Environmental Aspects of Energy Use in Large Indian Metropolises
VOLUME I

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Contents

Preface

Chapter 1 Introduction 1-5
- 1.1. Urbanisation and energy-economic-environment linkages 1
- 1.2. India: urbanisation trend, energy and environmental issues 2

Chapter 2 Scope and objectives 6-7
- 2.1. Issues under examination 7
  - 2.1.1. Transport sector
  - 2.1.2. Power sector
  - 2.1.3. Industrial sector

Chapter 3 City characteristics: demography, energy and environment 8-60
- 3.1. The study area 8
  - 3.1.1. Delhi 8
  - 3.1.2. Calcutta 10
  - 3.1.3. Mumbai 12
  - 3.1.4. Bangalore 14
- 3.2. Demography 16
  - 3.2.1. Population 16
  - 3.2.2. Density 18
- 3.3. Transport sector profile 18
- 3.4. Power sector profile 21
- 3.5. Industrial sector profile 34
- 3.6. Air quality profile 36
  - 3.6.1. Standards 37
  - 3.6.2. Delhi 38
    - 3.6.2.1. Total suspended particulate
    - 3.6.2.2. Sulphur dioxide
    - 3.6.2.3. Oxides of Nitrogen
    - 3.6.2.4. Lead
    - 3.6.2.5. Carbon monoxide
  - 3.6.3. Calcutta 43
    - 3.6.3.1. Total suspended particulate
    - 3.6.3.2. Sulphur dioxide
    - 3.6.3.3. Oxides of Nitrogen
  - 3.6 4. Mumbai 46
    - 3.6.4.1. Total suspended particulate
    - 3.6.4.2. Sulphur dioxide
    - 3.6.4.3. Oxides of Nitrogen
    - 3.6.4.4. Lead
    - 3.6.4.5. Carbon monoxide
  - 3.6.5. Bangalore 49
    - 3.6.5.1. Total suspended particulate
    - 3.6.5.2. Sulphur dioxide
    - 3.6.5.3. Oxides of Nitrogen
    - 3.6.5.4. Lead

3.7. Energy use pattern 53
3.8. Environmental impacts of energy production and consumption .. 57

Chapter 4 Framework for analysis 61-77
4.1. Transport sector 61
  4.1.1. Energy demand and emissions using LEAP model 61
    4.1.1.1. What is LEAP
    4.1.1.2. LEAP framework
    4.1.1.3. Growth of vehicles and travel demand
    4.1.1.4. Energy demand
    4.1.1.5. Emissions
  4.1.2. Scenario construction and assumption using LEAP 66
  4.1.3. Financial analysis of alternative clean technologies 68
4.2. Power sector 69
  4.2.1. Power requirement and supply potential 69
  4.2.2. Scenario construction and assumptions 70
    4.2.2.1. Business-as-usual or base case
    4.2.2.2. Alternative scenarios to contain energy demand and emissions
4.3. Industrial sector 72
  4.3.1. Identification of energy intensive industries 73
  4.3.2. Trends in energy intesities in industries in Delhi 75
  4.3.3. Estimation of emissions from the energy intensive industries 77

Chapter 5 Results and analysis 78-192
5.1. Transport sector 78
  5.1.1. BAU scenario 78
    5.1.1.1. Growth trends of motor vehicle registrations
    5.1.1.2. Changes in vehicle registration composition
    5.1.1.3. Projection of passenger vehicles with attrition
    5.1.1.4. Ownership of private vehicles
    5.1.1.5. Travel demand and modal split
    5.1.1.6. Energy demand
    5.1.1.7. Emissions
  5.1.2. Alternative scenarios 107
    5.1.2.1. Scenario 1: Strengthening of public buses
    5.1.2.2. Scenario 2: Introduction of efficient technology and cleaner fuel
    5.1.2.3. Scenario 3: Strengthening of public buses, efficient technologies and cleaner fuel
  5.1.3. Results under three scenarios compared to BAU 109
    5.1.3.1. Energy demand
    5.1.3.2. Emissions
  5.1.4. Financial viability of cleaner technologies 127
    5.1.4.1. Battery operated vehicles as a substitute to autorickshaws
    5.1.4.2. Compressed natural gas vehicles as a substitute to older model cars

5.2. Power sector 131
  5.2.1. BAU scenario 131
    5.2.1.1. Demand projections to examine changing requirements
    5.2.1.2. Comparison of per capita consumption
    5.2.1.3. Comparison of local generation and purchased power
    5.2.1.4. Fuel consumption and emissions
  5.2.2. Alternative strategies 143
    5.2.2.1. Scenario 1: Better housekeeping and operating practices
    5.2.2.2. Scenario 2: Improved performance of control technologies
    5.2.2.3 Scenario 3: Adoption of low-NO_x cumbustion technologies
    5.2.2.4. Scenario 4: Adoption of sorbent injection technology for SO_2 control
    5.2.2.5. Scenario 5: Alternative scenarios for SO_2 reduction
    5.2.2.6. Scenario 6: Coal washing for TSP reduction
  5.2.3. Introduction of cleaner coal based technologies 149
    5.2.3.1. Atmospheric fluidized-bed combustion
    5.2.3.2. Pressurized fluidized-bed combustion technology
    5.2.3.3. Integrated gasification combined-cycle
5.3. Industrial sector 151
  5.3.1. Energy intensity and emissions in Delhi 151
    5.3.1.1. Manufacture of food products
    5.3.1.2. Basic chemicals and chemical products (except products of petroleum and coal)
    5.3.1.3. Cotton textile
    5.3.1.4. Basic metal and alloys industries
    5.3.1.5. Rubber, plastic, petroleum and coal products; processing of nuclear fuels
    5.3.1.6. Non-metallic mineral products
    5.3.1.7. Man-made fibers
    5.3.1.8. Paper and paper products

Chapter 6 Summary and conclusions 193-207
6.1. Growth of cities and population density 194
6.2. Transport sector 194
  6.2.1. Growth and composition of registered vehicles 194
  6.2.2. Vehicle projections with attrition factor 195
  6.2.3. Ownership pattern of vehicles 195
  6.2.4. Passenger travel demand 195
  6.2.5. Framework for analysis 196
    6.2.5.1. Total and per capita energy demand
    6.2.5.2. Emissions
  6.2.6. Abatement strategies and reduction potential 198
  6.2.7. Financial viability of alternate fuels 200
6.3. Power sector 200
  6.3.1. Total and per capita electricity consumption 200
  6.3.2. Need for reliable power supply from grid 200

6.3.3. Need for privatization and reforms 201
6.3.4. Share of local generation 202
6.3.5. Energy use and specific fuel consumption norms 202
6.3.6. Emissions 202
6.3.7. Abatement strategies and reduction potential 203
6.4. Industrial sector 205
6.4.1. Food products, sugar and breweries 205
6.4.2. Basic chemical and chemical products 205
6.4.3. Cotton textile 205
6.4.4. Basic metal and alloy 205
6.4.5. Rubber, plastic, petroleum and coal products 206
6.4.6. Non-metallic mineral products 206
6.4.7. Wool, silk and man-made fibre textile 206
6.4.8. Paper, paper products, printing and publishing 206
6.4.9. Location policy 206
6.4.10. Need for a detailed inventory 207

References

Annexures

Volume II 1-137

List of tables

Table 3.1. Population projections for 2001 (in million)
Table 3.2. Growth of population in the four cities
Table 3.3. Growth of registered motor vehicles
Table 3.4. Motor vehicle composition (%)
Table 3.5. Details of power generating units in Delhi
Table 3.6. Plantwise installed capacity in Delhi (MW)
Table 3.7. Generation in Delhi (GWh)
Table 3.8. Electricity sales by consumer category in Delhi (GWh)
Table 3.9. Details of plants in Calcutta
Table 3.10. Plantwise installed capacity in Calcutta (MW)
Table 3.11. Total electricity generation from plants in Calcutta (GWh)
Table 3.12. Electricity sales by category in Calcutta (GWh)
Table 3.13. Details of power plants in Mumbai
Table 3.14. Installed capacity in Mumbai (MW)
Table 3.15. Generation in Mumbai by TEC
Table 3.16. Sales of power by TEC in Mumbai
Table 3.17. Number of manufacturing industries in the four cities
Table 3.18. Ambient air quality standards: eight hourly average, prior to 1993
Table 3.19. Ambient air quality standards, effective from May 1994
Table 3.20. Ambient air quality recorded in three stations in Bangalore (1993/94)
Table 3.21. Energy consumption pattern in Delhi
Table 3.22. Energy consumption pattern in Calcutta (in thousand tonnes)
Table 3 23. Energy consumption pattern in Greater Mumbai
Table 3.24. Sectoral energy use in Bangalore during 1986/87 (TJ)
Table 3.25. Trends in sectoral share of emissions in Delhi
Table 3.26. Sectoral emissions in Delhi (tonne/day)
Table 3.27. Annual emission in Calcutta and sectoral contributions (thousand tonnes)
Table 3.28. Source contribution to emissions in Greater Mumbai, 1992

Table 4.1. National Industrial Classification for manufacturing industries
Table 4.2. Identified energy intensive manufacturing industries in the four states
Table 4.3. Conversion factors for fuels (to oil equivalent)
Table 4.4. Emission factors

Table 5.1. Vehicular composition with attrition factor - past, present and future
Table 5.2. Number of vehicles (with attrition) per thousand persons
Table 5.3. Average seating capacity, load carried and daily utilization of vehicles
Table 5.4. Travel demand and its distribution by different modes and their technologies
Table 5.5. Average fuel efficiency (km/l)
Table 5.6. Annual per capita fuel requirement in passenger vehicles (kgoe/person)
Table 5.7. Emission factors of Indian vehicles
Table 5.8. Changes in contribution of CO emission by modes (%)
Table 5.9. Changes in contribution of HC emission by modes (%)
Table 5.10. Changes in contribution of NO_x emission by modes (%)
Table 5.11. Changes in contribution of SO_2 emission by modes (%)
Table 5.12. Changes in contribution of TSP emission by modes (%)

Table 5.13. Changes in contribution of Pb emission by modes (%)
Table 5.14. Changes in travel demand share by different modes in 2010/11 (%)
Table 5.15. Changes in technological and fuel mix in 2010/11
Table 5.16. Growth in total energy requirement under alternative scenarios ('000 toe)
Table 5.17. Percentage difference in emissions in alternative scenarios compared to BAU in 2010/11
Table 5.18. Ratio of present value of 3 wheeler and BOV
Table 5.19. Ratio of present value of CNG car and conventional car
Table 5.20. Availability of power in Delhi (GWh)
Table 5.21. Availability of power in Calcutta (GWh)
Table 5.22. Availability of power in Mumbai (GWh)
Table 5.23. Estimated coal consumption in Delhi ('000 tonnes)
Table 5.24. Estimated oil consumption in Delhi (kl)
Table 5.25. Estimated natural gas consumption in Delhi (million cubic meter)
Table 5.26. Estimated coal consumption in Calcutta ('000 tonnes)
Table 5.27. Estimated oil consumption in Calcutta (kl)
Table 5.28. Emission factors in power plant
Table 5.29. Base case emissions in Bombay
Table 5.30. Growth of energy intensive (as per ASI data) in the states of Delhi, Est Bengal, Maharashtra and Karnataka during 1989/90 and 1993/94
Table 5.31. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 20-21 (Food Products, sugar & breweries) in Delhi for the years 1989/90 and 1993/94
Table 5.32. Total energy consumption and percentage shares of various fuels in sector 20-21 (Food products, sugar and breweries) in Delhi during 1989/90 and 1993/94
Table 5.33. Fuel-wise contribution of emissions from industry 20-21 in Delhi
Table 5.34. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 30 (manufacture of basic chemicals and chemical products) in Delhi for the years 1989/90 and 1993/94
Table 5.35. Total energy consumption and percentage shares of various fuels in sector 30 (manufacture of basic chemicals and chemical products) in Delhi during 1989/90 and 1993/94
Table 5.36. Fuel-wise contribution of emissions from industry 30 in Delhi
Table 5.37 Energy intensity, value addition, input cost and gross value of plant and machinery for sector 23 (manufacture of cotton textiles) in Delhi for the year 1989/90 and 1993/94
Table 5.38. Total energy consumption and percentage shares of various fuels in sector 23 (manufacture of cotton textiles) in Delhi during 1989/90 and 1993/94
Table 5.39 Fuel-wise contribution of emissions from industry 23 in Delhi
Table 5.40 Energy intensity, value addition, input cost and gross value of plant and machinery for sector 33 (basic metals an alloy industries) in Delhi for the years 1989/90 and 1993/94
Table 5.41. Total energy consumption and percentage shares of various fuels in sector 33 (basic metals and alloy industries) in Delhi during 1989/90 and 1993/94
Table 5.42. Fuel-wise contribution of emissions from industry 33 in Delhi
Table 5.43. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 31 (manufacture of rubber, plastic, petroleum and coal products) in Delhi for the years 1989/90 and 1993/94
Table 5.44. Total energy consumption and percentage shares of various fuels in sector 31

(manufacture of rubber, plastic, petroleum and coal products) in Delhi during 1989/90 and 1993/94
Table 5.45. Fuel-wise contribution of emissions from industry 31 in Delhi
Table 5.46 Energy intensity, value addition, input cost and gross value of plant and machinery for sector 32 (manufacture of non-metallic mineral products) in Delhi for 1989/90 and 1993/94
Table 5.47. Total energy consumption and percentage shares of various fuels in sector 32 (manufacture of non-metallic mineral products) in Delhi during 1989/90 and 1993/94
Table 5.48. Fuel-wise contribution of emissions from industry 32 in Delhi
Table 5.49. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 24 (manufacture of man-made fibers) in Delhi for the year 1989/90 and 1993/94
Table 5.50 Total energy consumption and percentage shares of various fuels in sector 24 (manufacture of man-made fibers) in Delhi during 1989/90 and 1993/94
Table 5.51. Fuel-wise contribution of emissions from industry 24 in Delhi
Table 5.52. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 28 (manufacture of paper and paper products) in Delhi for the year 1989/90 and 1993/94
Table 5.53. Total energy consumption and percentage shares of various fuels in sector 28 (manufacture of paper and paper products) in Delhi during 1989/90 and 1993/94
Table 5.54. Fuel-wise contribution of emissions from industry 28 in Delhi

List of figures

Figure 3.1. Map of Delhi
Figure 3.2. Map of Calcutta
Figure 3.3. Map of Mumbai metropolitan region
Figure 3.4. Map of Bangalore
Figure 3.5. Air quality trends in Delhi
Figure 3.6. Air quality trends in Calcutta
Figure 3.7. Air quality trends in Mumbai
Figure 3.8. Air quality trends in Bangalore

Figure 4.1. LEAP schematic diagram for urban transport

Figure 5.1. Trends in vehicle registration
Figure 5.2. Growth of registered vehicles with attrition factors
Figure 5.3. Growth in passenger travel demand and modal split
Figure 5.4. Transport energy requirement under BAU scenario
Figure 5.5. CO emissions in the four cities
Figure 5.6. HC emissions in the four cities
Figure 5.7. NO_x emissions in the four cities
Figure 5.8. SO_2 emissions in the four cities
Figure 5.9. TSP emissions in the four cities
Figure 5.10. Pb emissions in the four cities
Figure 5.11. Energy requirement in the alternate scenarios
Figure 5.12. Reduction(-)/addition(+) in energy demand wrt BAU
Figure 5.13. Energy mix pattern under alternative scenarios (Delhi)
Figure 5.14. Energy mix pattern under alternative scenarios (Calcutta)
Figure 5.15. Energy mix pattern under alternative scenarios (Mumbai)
Figure 5.16. Energy mix pattern under alternative scenarios (Bangalore)
Figure 5 17. Reduction(-)/ addition(+) in CO emissions w.r.t. BAU
Figure 5.18. Reduction(-)/ addition(+) in HC emissions w.r.t. BAU
Figure 5.19. Reduction(-)/ addition(+) in NO_x emissions w.r.t. BAU
Figure 5.20. Reduction(-)/ addition(+) in SO_2 emissions w.r.t. BAU
Figure 5.21. Reduction(-)/ addition(+) in TSP emissions w.r.t. BAU
Figure 5.22. Reduction(-)/ addition(+) in Pb emissions w.r.t. BAU
Figure 5 23. Total requirement of power in the three cities
Figure 5.24. Per capita non-industrial consumption of electricity
Figure 5.25. Purchase of power
Figure 5 26. Comparative profile of TSP, NO_x, and SO_2 (1994)
Figure 5 27. Base case emissions in Delhi
Figure 5.28. Base case emissions in Calcutta
Figure 5.29. Base case emissions in Mumbai
Figure 5.30. Alternative scenarios for reduction in TSP
Figure 5.31. Alternative scenarios for NO_x reduction
Figure 5.32. Alternative scenarios for SO_2 reduction
Figure 5.33. Reduction in TSP in Delhi with washing of coal
Figure 5.34. Growth of industries in Delhi 1989 & 1993/94
Figure 5.35. Growth of industries in West Bengal 1989/90 & 1993/94
Figure 5.36. Growth of industries in Maharashtra 1989/90 & 1993/94

Figure 5.37. Growth of industries in Karnataka 1989/90 & 1993/94
Figure 5.38. Changes in energy intensity of industry 20-21 during 1989/90 & 1993/94
Figure 5.39. Changes in energy intensity of industry 30 during 1989/90 and 1993/94
Figure 5.40. Changes in energy intensity of industry 23 during 1989/90 and 1993/94
Figure 5.41. Changes in energy intensity of industry 33 during 1989/90 and 1993/94
Figure 5.42. Changes in energy intensity of industry 31 during 1989/90 and 1993/94
Figure 5.43. Changes in energy intensity of industry 32 during 1989/90 and 1993/94
Figure 5.44. Changes in energy intensity of industry 24 during 1989/90 and 1993/94
Figure 5.45. Changes in energy intensity of industry 28 during 1989/90 and 1993/94

List of abbreviations

AFBC : Atmospheric Fluidized Bed Combustion
ARAI : Automotive Research Association of India
ASI : Annual Survey of Industries
BAU : business-as-usual
BEST : Bombay Electric Supply and Transport
BMC : Bombay Metropolitan Council
BMR : Bombay Metropolitan Region
BMRDA : Bombay Metropolitan Region Development Authority
BOVs : Battery Operated Vehicles
BSES : Bombay Suburban Electric Supply
Ca/S : calcium-to-sulfur
CAGR : compound annual growth rate
$CaSO_4$: Calcium Sulfate
CBD : Central Business District
CEA : Central Electricity Authority
CESC : Calcutta Electric Supply Corporation
CGSC : Greater Calcutta Gas Supply Corporation
CMA : Calcutta Metropolitan Area
CMC : Calcutta Municipal Corporation
CMDA : Calcutta Metropolitan Development Authority
CNG : Compressed Natural Gas
CO : Carbon Monoxide
CPCB : Central Pollution Control Board
CSME : Centre for Study of Man and Environment
DDA : Delhi Development Authority
DESU : Delhi Electricity Supply Undertaking
DMA : Delhi Metropolitan Area
DSIDC : Delhi State Industrial Development Corporation
DTC : Delhi Transport Corporation
DVB : Delhi Vidyut Board
DVC : Damodar Valley Corporation
EDB : Environmental Database
EMU : Electric Motive Unit
ESPs : Electrostatic Precipitators
FGD : Flue Gas Desulphurisation
GAIL : Gas Authority of India Limited

HCV : Heavy Commercial Vehicle
HSD : High Speed Diesel
IGCC : Integrated Gasification Combined Cycle
IIP : Indian Institute of Petroleum
IP : Indraprastha
IPT : Intermediate Public Transport
KEB : Karnataka Electricity Board
KPC : Karnataka Power Corporation
LCV : Light Commercial Vehicle
LDO : Light Diesel Oil
LEAP : Long Range Energy Alternatives Planning
LNBs : Low-NO_x burners
LSHS : low sulphur high stock
MC : Multi Cyclones
MCD . Municipal Corporation of Delhi
MCFD : million cubic feet per day
MCGB . Municipal Corporation of Greater Bombay
MGL : Mahanagar Gas Limited
MRTS : Mass Rapid Transit System
MSEB : Maharashtra State Electricity Board
NAAQM : National Ambient Air Quality Monitoring
NCR : National Capital Region
NDMC New Delhi Municipal Committee
NEERI . National Environmental Engineering Research Institute
NIC . National Industrial Classification
NO_2 : Nitrogen Oxide
NREB : Northern Region Electricity Board
NTPC . National Thermal Power Corporation
NVA . Net Value Added
ONGC : Oil and Natural Gas Commission
Pb : Lead
PFBC . Pressurized Fluidized Bed Combustion
ppm per unit volume
RTO : Regional Transport Office
SIDA : Swedish International Development Cooperation
SNCR : Selective Noncatalytic Reduction
SO_2 : Sulphur dioxide
SPM : Suspended Particulate Matter
TEC : Tata Electric Companies

TERI	:	Tata Energy Research Institute
TSP	:	Total Suspended Particulate
UNEP	:	United Nations Environment Programme
USEPA	:	United States Environment Protection Agency
WBSEB	:	West Bengal State Electricity Board
WHO	:	World Health Organisation

Preface

The report is divided into two volumes, Volume I and Volume II. Volume I, which is this report is divided into six chapters. The first chapter introduces the study in the four cities viz., Delhi, Calcutta, Mumbai and Bangalore. The second chapter gives the scope and objectives of the study. The third chapter analyses the city characteristics with respect to location, climate, demographic parameters, sectoral energy consumption levels and air quality status and draws comparisons among the four cities. The fourth chapter gives the detailed methodological framework for analyzing energy consumption in transport, power and manufacturing industrial sector and related emissions. Chapter four also defines the various policy issues under alternative scenarios for analysis. The fifth chapter presents the results and analysis of energy consumption and emissions in the three sectors under the business-as-usual (uncontrolled or as per present trends) scenario and alternative controlled scenarios (various policy issues). The sixth chapter gives the summary and conclusions.

Volume II, which is a separate report contains the annexure to Volume I and II gives the statistical tables generated during the analysis of secondary data.

CHAPTER 1

Introduction

1.1. Urbanisation and energy-economic-environment linkages

Energy is a key input for economic development that includes *inter alia*, fuel for cooking, heating and lighting to meet basic needs, power for industrial growth, and petroleum products for transportation. The production and transformation of energy (production of power from fossil fuels) is in itself, an important economic sub-sector. The supply and demand of virtually every type of energy generates varying degrees of environmental externalities which affect human health, ecological stability and economic development. These effects can occur at the household, local, regional or transnational level.

While the environmental effects of energy use may be geographically dispersed, there are compelling reasons to focus on urban-driven problems. Specifically, this is because:

(a) With the concentration of population and economic activities in urban areas, there are certain energy-related environmental problems which are generated by rapidly developing cities that do not occur in rural areas.

(b) Urban consumers use energy more intensively than their rural counterparts. Urbanisation also leads to the shift from traditional to more modern fuels. Studies have shown that the use of modern fuels is highly concentrated in cities and there is a high degree of correlation between rising energy demand and use of modern fuels in cities.

(c) In the process of consuming and transforming energy resources, cities cast an environmental "shadow" over peri-urban and rural areas.

(d) Metropolitan demand for energy is accelerating due to the growth of income in urban areas. The virtual explosion of personalized modes of transport like cars and two wheelers in cities and the rising demand for energy-intensive electrical gadgets are the consequences of the rise in income of city-dwellers.

(e) Urban energy production and consumption are commercial activities which are susceptible to management by market oriented policy actions, an option which is often not available for reaching rural consumers whose energy use may not be monetized.

(f) The air quality in metropolitan cities is found to be unsatisfactory with coal-fired power plants, energy use in manufacturing industries and transportation sector bearing most of the responsibility.

Several studies have revealed that many large size cities in Asia are on the threshold of a major environmental crisis in the form of air pollution from fossil fuel based generation of electric power, from combustion of petroleum products in vehicles, and from fossil fuel use in industries. The deteriorating air quality in cities is a result of rapid economic expansion, rise in population, increased industrial output and unprecedented growth of personalized vehicles. Unless adequate measures are taken in advance to enhance energy supply and optimize its use, the shortage may constrain urban development. Policies and strategies related to the planning, design, construction and use of urban settlements influence, directly or indirectly, the consumption of energy. It is therefore, worthwhile to develop a policy-analytical framework to understand the structure of urban energy use, its supply and demand related environmental impacts, and devising strategies for choosing and pursuing solutions.

1.2. India: urbanisation trend, energy and environmental issues

In India, the pace of urbanisation has been increasing, especially in the last four decades. In 1951, the urban population was 62 million (17.3 per cent of the total). By 1991, this number had swelled to nearly 217 million — with one in every four persons living in urban areas (*Nanda, 1991*). With only 27 per cent of India's population living in urban areas, it is often proclaimed that India lives in its villages. However, in terms of absolute numbers the 217 million urban residents would themselves make up one of the largest countries in the world. With moderate rates of growth of urban population, it is estimated that by 2015 A.D. over 50 per cent of India's population will be living in urban areas and there will be over 50 cities with a population of one million and above (*Mehta, Raghupathi and Sharma, 1994*). There has also been a steady rise in the population of large cities. According to 1991 census, there are 23 metropolitan cities (each with over one million people) in India, accounting for roughly one-third of urban population and one-twelfth of total population. Over 50 per cent of the population living in these metropolitan cities lives in the five giant metropolises — Calcutta (11.86 million), Mumbai (9.93 million), Delhi (9.42 million), Madras (5.36 million) and Bangalore (4.09 million).

Urbanisation while having positive impact on income levels, employment and production has brought with it air, water and noise pollution problems. The overall quality of urban environment has deteriorated over the years with the largest cities reaching saturation points and being unable to cope with the increasing pressure on their infrastructure. Metropolitan living has become a problem for the common man and the capacity of the municipal government to improve the quality of life is extremely limited. While cities are considered 'engines of economic growth', given the fact that Indian cities contribute nearly 60% of the national income they are also inherently unsustainable in terms of level and type of fuel demand in different economic sectors and related pollution problems. A number of city specific studies have been conducted in India to understand the energy use pattern. The cities include Hyderabad (*Alam, 1985*); Bangalore (*Reddy and Reddy, 1983*), Pune (*Nair and Krishnayya, 1985*), Ahmedabad (*Ganapathy and Padmanabhan, 1985*) and Delhi (*Bose, 1996a; TERI, 1988, 1989, 1990, 1992*). Similarly, a few studies were done on the environmental dimension of urban energy supply/demand (*Bose, 1990, 1996b, 1996c; TERI, 1995; GHK International, 1995; World Bank, 1997*).

Air pollution is a serious and widespread problem in the urban areas -- where, automobiles are the major contributors (carbon monoxide, hydrocarbons, lead and nitrogen oxides) -- and to a few other areas with a concentration of industries (toxic gases) and thermal power plants (flyash and total suspended particulate). Automobiles, industries and power plants consume many tonnes of fuel daily resulting in mass emissions of various type of pollutants, putting an average urban citizen to greater health risk.

The Central Pollution Control Board (CPCB) has been monitoring air quality in the major towns/cities since 1984. Over the years the number of monitoring stations have increased. Out of 290 stations spread over 92 cities/towns under the National Ambient Air Quality Monitoring (NAAQM) network, 188 stations have already come into operation, 26 stand withdrawn and 38 are to be relocated (*CPCB, 1994*). Besides the meteorological parameters, the air quality parameters monitored regularly are sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and suspended particulate matter (SPM) or total suspended particulates (TSP). In addition, carbon monoxide (CO) and lead (Pb) are also monitored by CPCB in a limited number of stations. The National Ambient Air Quality Standards for these pollutants are available for three kinds of locations, viz., (i) sensitive area, (ii) industrial area, and (iii) residential, rural and other areas.

In the transport sector, the vehicle production in the country between 1971 and 1990 has increased four times which has resulted in increased frequency of urban trips (*ACMA, 1993*). While travel demand and number of vehicles has gone up, the road space availability has not kept pace with the increased travel demand and the growth in the number of vehicles. This has resulted in heavy road traffic congestion in most of the cities. On the one hand, the vehicle mix in cities has aggravated congestion and air pollution, while on the other, specifically production of buses and their design for mass transportation in urban areas has not received adequate attention in the national automobile policy. Traffic congestion has become a common sight and a problem that the commuters have to put up with every day. Reduced vehicle travel speeds lead to longer travel time, extra fuel consumption, extra air pollutants, extra discomfort to road users, and therefore degradation of the urban environment.

Four factors make pollution from road motor vehicles very serious in very large conurbations like Delhi, Calcutta, Mumbai and Bangalore. First, many vehicles are in poor condition, creating more particulates and burning fuels inefficiently. Certain types of engines, such as 2-strokes, are particularly bad, though new options for improving their efficiency may be available soon. The 2-stroke engines emit HCs and smoke at a much higher rate than the 4-stroke engines and produce most of the HC emissions. For instance, nearly 70% of the total registered fleet in Delhi comprise of two wheelers of which over 90% run on 2-stroke engines, while the remaining are 4-stroke. Second, lower-quality fuels are used, leading to the emissions of far greater quantities of pollutants. Third, motor vehicles are concentrated in a few large cities. Fourth, a far larger percentage of the population moves and lives in the open air and is thus exposed far more to automotive pollutants.

There has been a dramatic increase and completely uncontrolled expansion of polluting industries within existing cities and residential neighbourhoods, contributing to water, air and soil pollution. Locations of industries, in turn, were not considered till recently from an environmental angle leading to many disastrous locational decisions within cities. The case of the Bhopal disaster, the explosion of the Union Carbide factory and the emission of toxic gases resulting in thousands of deaths and health disorders illustrates the problem of location of hazardous industries as an extreme case. Relocation of 'non-conforming' industries has been initiated only on a limited scale. An adaptation of clean technologies should find more relevance, but has not been adequately pursued.

A major air pollution problem associated with coal plants is the result of the emission of SO_2, NO_x, TSP, HCs, radionucleids, aldehydes and CO_2. The polluting gases have, individually, an impact on both human health as well as the ecosystem; the extent of which is determined by the dosage received, the time span over which it is received and the average well-being of the recipient population. Control measures exist for all the major pollutants at the pre and post combustion stages as well as the process stage. At present the installation of electrostatic precipitators (ESP) for the control of TSP emissions is mandatory in India. ESPs are generally reported to operate at efficiencies of 99 per cent and above, the efficiencies generally being relatively insensitive to particle size but grade efficiency curves indicate a minimum in the 0.2-2.0 μm range (*Wallin, 1986*). However, the efficiency of particulate removal below 0.1 μm is poor. This is important given that the smaller sized particles penetrate deeper into the lung and therefore can be more toxic (*Ottinger, et al, 1990*).

In view of the potential environmental consequences of continuing growth of large metropolises in Asia, and India in particular, the Department of Research Cooperation, Swedish International Development Cooperation Agency (SIDA), Stockholm, has entrusted a three year study (1994-97) entitled *"Environmental Aspects of Energy Uses in Large Indian Metropolises"* to the Tata Energy Research Institute (TERI), New Delhi. This study has made an attempt to - (1) analyze the energy-economic-environmental implications in the four metropolitan cities in India - Delhi, Calcutta, Mumbai and Bangalore, with particular reference to the three sectors viz., transport, power and industry, and (2) examine a number of issues in each sector with an overall strategy to reduce energy demand and emissions in the four cities. The common methodological framework adopted in the study for analyzing the four cities has a wider applicability beyond India in other parts of Asia. As a part of this study, TERI has conducted two workshops, first one in New Delhi on November 15, 1994 and the second one in Bangalore on February 23, 1996. The scope of the first workshop was mainly to discuss the project design and methodological framework of the study. While in the second workshop, the scope was mainly to identify list of policy issues in the three sectors - transport, power and industry - for a detailed investigation. These two workshops have immensely helped TERI in focussing the scope of work and in drawing some important policy conclusions for Indian cities.

CHAPTER 2

Scope and objectives

The overall scope of the study is to develop a methodological framework, flexible enough, for analyzing the nature and magnitude of air pollution relating to energy demand/ consumption in large urban agglomerations in India with different socio-economic and geographical features. While analyzing the environmental dimension of energy use, the study is restricted to the three major urban polluting sectors viz., transport, power plants and industry located within the city municipal boundaries. From a policy perspective, it is just as important to understand how large size cities with varied mix of socio-economic activities and forms compare with one another as it is to understand how energy use has changed over time in different sectors and the resulting impact on emissions. With growing urbanization it is expected that the changes in socio-economic characteristics like, real household income, ownership of personalized vehicles and their utilization, per capita power demand, mix of industries, real value addition by industries, city size, population density and other factors will affect changes in fuel use and environmental quality. Further, it is important to identify, analyze and compare the major policy issues of concern in each sector for the formulation of an overall strategy to contain energy demand and to mitigate emissions. Such a city level comparative framework in a rapidly developing economy, like India, is expected to generate a methodology which can further be applied to a spectrum of large cities in Asia for analyzing energy demand and environmental issues.

Grounded in this vision, the study has made an attempt to systematically collect and collate secondary data from published sources, and analyzed the energy-economic-environmental implications due to the changes in three major sectors, viz, transport, power and industry in four large size cities in India - Delhi, Calcutta, Mumbai and Bangalore.

In addition, the study has made an attempt to analyze a set of issues in each sector which are important for the future fuel use in these cities in order to improve urban environment, based on careful comparisons of the four cities.

The specific elements of the study in the four cities are:

- to characterize each city by analyzing spatial and temporal data on demographic, sectoral energy use and air quality;
- to develop a common but flexible framework for analyzing the energy consumption pattern in the three major sectors -- transport, power plants and industry -- and estimate resultant emissions in past, present and future;
- to estimate the pattern of energy use in each sector and the resultant emissions of CO, HC, NO_x, SO_2, TSP and Pb;

- to identify alternate scenarios as policy measures for an indepth analysis of the environmental implications of energy use in different sectors over a period of time; and
- to compare the scenario results with the business-as usual case in each sector and measure the impacts.

Such an indepth analysis in large urban agglomerations would facilitate the formulation of various action plans and strategies at the city level to contain energy demand and environmental degradation.

2.1. Issues under examination

The following issues were identified during the second project review workshop held in Bangalore on February 23, 1996 for a detailed energy-environment impact assessment at the city level in different sectors.

2.1.1. Transport sector

- trends in vehicular growth and its composition;
- strengthening of mass transport by facilitating a shift from personal to public buses;
- penetration of different types of technologies like four stroke gasoline engines and vehicles fitted with catalytic convertors;
- introduction of alternate fuels, like Compressed Natural Gas (CNG), propane/LPG, and electricity for battery charging; and
- financial analysis of introducing battery operated and compressed natural gas vehicles.

2.1.2. Power sector

- trends in share of power generation within city limits;
- growth of electricity consumption; and
- technological performance of the power plants and options (at the source and end of pipe) for ameliorating emissions.

2.1.3. Industrial sector

- identification of energy intensive industries;
- structural changes in energy intensities;
- change in energy demand and the fuel composition;
- technological upgradation of plants and machinery;
- change in net value added of industrial products; and
- industrial locational impacts.

CHAPTER 3

City characteristics: demography, energy and environment

3.1. The study area

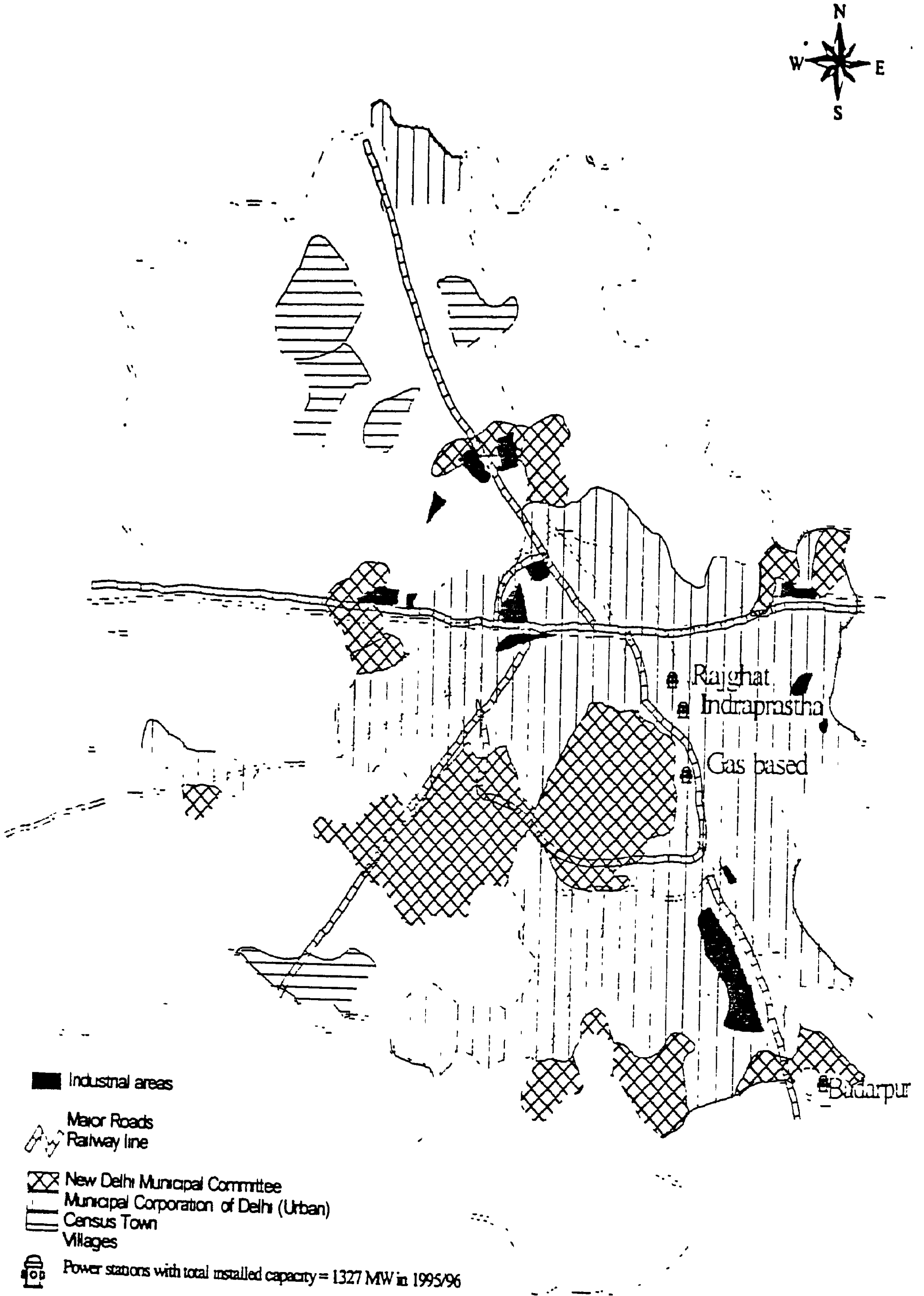
3.1.1. Delhi

The state of Delhi, in short Delhi, is situated in North of India, on the banks of the river Yamuna and sprawls over 1483 sq.km (148300 ha), with 47% comes under urban and the remaining 53% under rural area. Delhi with a total population of around 9.42 million in 1991 (with 90% urban and 10% rural), is located 160 km south of Himalaya, between the latitudes of 28°24 17 and 28°53 00'N and the longitudes of 76°50'24" and 77°20'37"E and at 216 metres above mean sea level.

Figure 3.1 is the map of Delhi, with greatest east-west length being 51.9 km and north-south width, 48.48 km. Delhi is surrounded by two states - Uttar Pradesh in the east and Haryana to the north, south and west. There are two distinct natural features that characterize Delhi - the Ridge and the river Yamuna. The latter forms the eastern boundary of the city. The Ridge is an extension of the Aravalli Hills, the oldest hill range of India which runs from the south of Delhi towards the north-east on the west of river Yamuna and further south-west into the State of Rajasthan. Total area of Delhi is bifurcated into three administrative divisions, viz., Delhi Municipal Corporation, New Delhi Municipal Committee, and Delhi Cantonment Board, with their share of covered area being 41%, 53%, 3% and 3% respectively.

Delhi replaced Calcutta as the capital in 1912 and has emerged as a multi-functional giant where the Central Government offices, public sector undertakings, the commercial traders and industries have grown in a haphazard manner. Delhi today manifests the symptoms of uncontrolled growth: distinct shortfalls in the infrastructural provisions of sewerage, water and power supply. Public transport facilities are inadequate. Unauthorized and uncontrolled land use, inadequate residential and commercial space, excessive rents, land speculation, unbalanced growth, and socio-economic compartmentalisation are other problems the city faces. The master plan of Delhi prepared in 1962 was meant to prevent or contain these problems. Instead after more than 35 years of "planning", not only have problems multiplied but, others have been added - air, water and noise pollution, rapidly dwindling green cover and degradation of the social environment, to mention a few.

To control the rapid growth of population in Delhi, the National Capital Region (NCR) was formed in 1986 with the idea of diverting the population and economic activities to satellite towns. The NCR spread over 30,242 sq.km. covers parts of the states of Haryana, U.P. and Rajasthan, besides the National Capital Territory of Delhi.


N
W
E
S
Rajghat
Indraprastha
Gas based
Badarpur
▇ Industrial areas
Major Roads
Railway line
▨ New Delhi Municipal Committee
Municipal Corporation of Delhi (Urban)
Census Town
Villages
Power stations with total installed capacity = 1327 MW in 1995/96

Geographic area = 1483 Sq Km (148300 ha)
Population - ~~[illegible]~~ million in 1990/91
9.42

Number of manufacturing industries in 1991
Large and medium scale = 173
Small scale = 6536

Total motor vehicles = 2.4 million in 1994/95

to scale

Figure 3.1 DELHI

For purposes of planning in Delhi, the Delhi Metropolitan Area (DMA) was formed, comprising of National Capital Territory of Delhi, Ghaziabad-Loni complex and Noida in U.P., Faridabad-Ballabhgarh Complex, Gurgaon, Bahadurgarh and Kundli in Haryana. The DMA which is spread over an area of 3182 sq.km. (over twice that of area of Delhi) is expected to contain the population of National Capital Territory of Delhi to 11.2 million by the year 2001 (Table 3.1).

Table 3.1. Population projections for 2001 (in million)

Region (Area)	Urban	Rural	Total
National Capital Region (30,242 sq.km)	23.4	9.1	32.5
Delhi Metropolitan Area (3,182 sq.km)	14.7	0.3	15.0
Delhi (1,483 sq km)	11.0	0.2	11.2

Source: National Capital Region Planning Board. Interim Development Plan - 2001

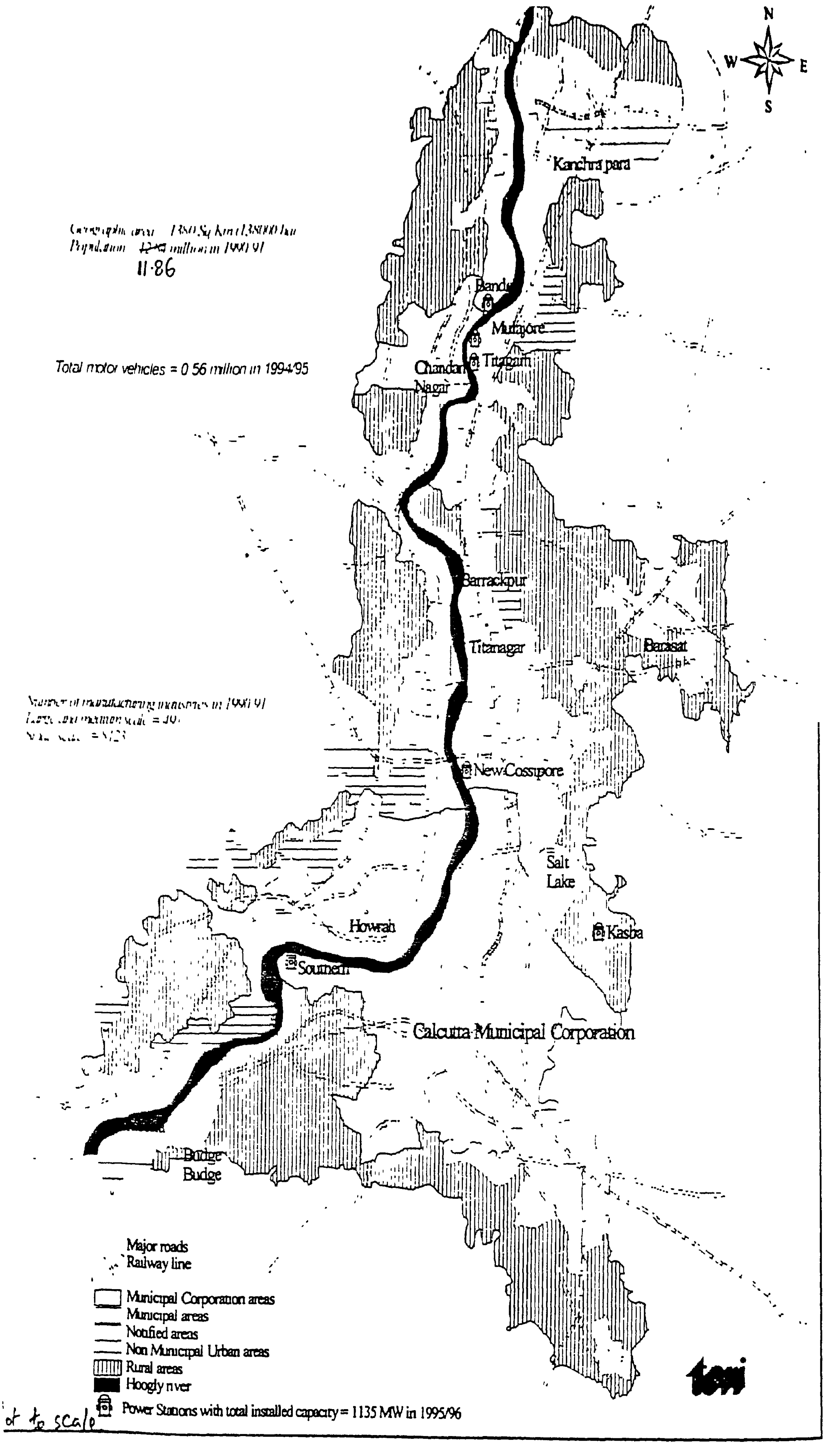
The climate of Delhi is mainly characterized by extreme dryness with an intensively hot summer and cold winter. About 80% of the rainfall occurs in the monsoon months, July - September. The annual average rainfall is 714.6 mm. January is the coldest month with the mean daily maximum temperature at 21.3°C and the mean daily minimum at 7 3°C. May and June are the hottest months with temperatures touching 46-47°C. Except during the monsoon months, winds are predominantly from a westerly or north-westerly direction and tend to be more northerly in the afternoon. Easterly and south-easterly winds are more common in the monsoon months.

3.1.2. Calcutta

The Calcutta Metropolitan Area (CMA), in short Calcutta, is located in Eastern India with a population of around 11.86 million in 1991 (with 93% urban and 7% rural). It covers an area of 1,380 sq.km (138000 ha) with generally a flat topography, and is located between the latitudes 22°20 and 23°0 N and the longitudes 88°02′ and 88°40′E.

As shown in Figure 3.2, Calcutta is primarily a linear city developed along the two sides on the eastern bank of river Hooghly and is bounded by the continuous industrial region. Nearly 49% of the total area under Calcutta comprised of 3 municipal corporations, 35% municipalities, 3 notified areas and the balance 51% is comprised of non-municipal urban and rural areas. Taking a cross section of linear pattern of urbanisation in Calcutta, the development becomes more sparse as one leaves the river banks.

Calcutta accommodates daily over 2 million floating population from its neighbourhood for various purposes. Large numbers of refugees crossed over and settled within Calcutta, after the partition of Bengal and the Indo-Pakistan war of 1971. In



Geographic area = 1380 Sq Km (138000 ha)
Population = ~~12.9~~ million in 1990/91
11·86

Total motor vehicles = 0.56 million in 1994/95

Number of manufacturing industries in 1990/91
Large and medium scale = 30
Small scale = 5123

Power Stations with total installed capacity = 1135 MW in 1995/96

ot to scale

Figure 3.2 CALCUTTA

addition, migrants from rural areas and neighbouring states account for the city's slum population, squatter's settlements and pavement dwellers. These put severe strain on the civic infrastructure like, water supply, drainage and sanitation, solid waste management, road improvement, "basti" improvement and its impact on air, water and noise pollution.

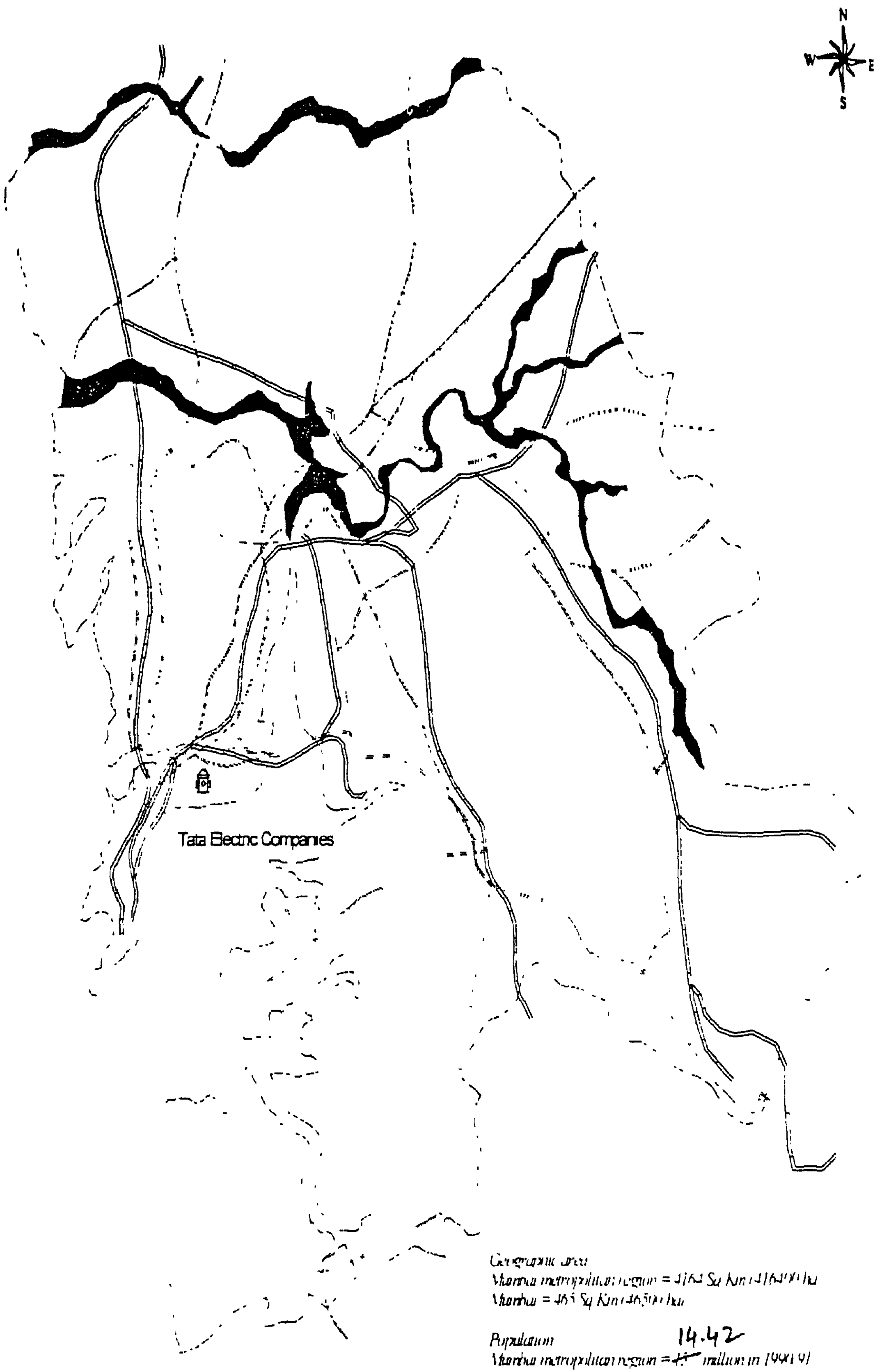
The Calcutta city with an area of 187.33 sq.km (18300 ha) and a population of 4.38 million in 1991, is the nerve centre of CMA or Calcutta. The city has around 7% of the total area available for road space. The problem of traffic congestion is rather acute, though a combination of circular railway, metro railway and river transport services has eased traffic flow to some extent since early 1990s. The city is administered by the Mayor-in-Council with all attributes of the cabinet form of municipal government. The area is divided into 141 wards, subgrouped into 15 borough committees.

The city of Calcutta has a humid climate nearly all the year round and has relatively hot summers. The city experiences about 1600 mm of rainfall during the monsoon months.

3.1.3. Mumbai (previously Bombay till 1996)

The Bombay Metropolitan Region (BMR), with a total population of 14.4 million in 1991 is spread over an area of 4164 sq.km (416400 ha). The region is located on India's west coast on a peninsula originally composed of seven islets, between the latitudes of 18°33 and 19°31 N and the longitudes of 72°45 and 73°28'E. Drainage and concentration have caused the islets to join and form the present-day Mumbai Island, with Arabian Sea to the west, and Mumbai Harbour and the outlet of Thana Creek to the east. The BMR is continuously expanding and now includes New Mumbai to the east of Thana Creek, and Mumbai Harbour and other areas further to the north and east. The BMR consists of three major Municipal Corporations, viz., the Municipal Corporation of Greater Bombay (MCGB), Thane Municipal Corporation and Kalyan Municipal Corporation. In addition there are 12 Municipal Councils, 37 Urban Centres and 1089 villages in the rest of BMR (*BMRDA, 1990*). The urban built up area accounts for 12% of the region's total area. Despite the rapid urban sprawl in the past few decades, agriculture and wetlands still accounts for the largest land use in the region accounting for 42% of its area.

As shown in Figure 3.3, Mumbai city is located on the western edge of the BMR separated from the mainland by Thane Creek and Vasai Creek. The city is located in Mumbai Island whilst the suburbs occupy the majority of the area of Salsette island. Municipal boroughs and villages or suburbs of Mumbai island and Salsette Island were joined in 1951 to form Greater Mumbai, in short Mumbai. In 1991, the total population of Mumbai was 9.93 million spread over an area of 465 sq.km (46500 ha) on the two islands. Mumbai Island is about 18 km long and 4.75 km wide narrowing to little more than



Geographic area
Mumbai metropolitan region = 4164 Sq Km (416400 ha)
Mumbai = 465 Sq Km (46500 ha)

Population
14.42
Mumbai metropolitan region = ~~15~~ million in 1990/91
Greater Mumbai = ~~10.6~~ million in 1990/91
9.93

Total motor vehicles = 0.67 million in 1994/95

Number of manufacturing industries 39308 in 1991

Major roads
Major rail
Mumbai Metropolitan Region (MMR)

Greater Mumbai (GM)
MMR excluding GM
■ Water bodies

Power stations with total installed capacity = 1337.5 MW in 1995/96

Not to scale

Figure 3.3 MUMBAI METROPOLITAN REGION

1.3 km width at the southern tip of the island where the central business district (CBD) is located around the old Fort area. Much of Mumbai is on a flat terrain, one-fourth of the area is below sea level. Two north-south ridges flank the flat area, the highest point being Malabar Hill to the south-west, 55 meters above sea level.

Since 1975 the Bombay Metropolitan Region Development Authority (BMRDA) has been coordinating planning and development in BMR. One of the principal concerns of BMRDA is to ensure orderly decentralization of economic growth and of development away from the Bombay Metropolitan Council (BMC) area, and in particular away from the Mumbai Island city.

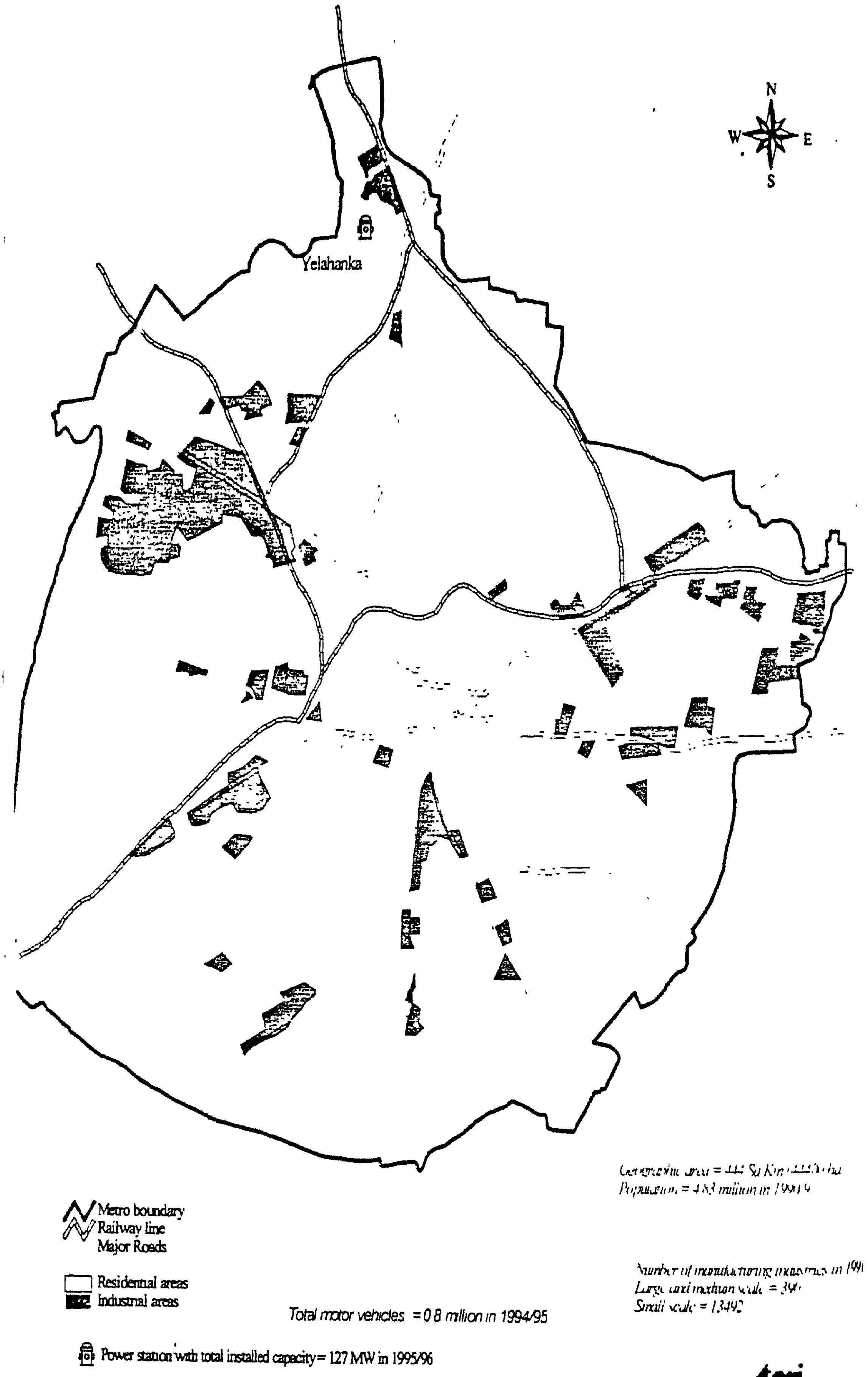
The climate of Mumbai is fairly equable since temperatures do not fluctuate significantly with seasons. The city has a mean elevation of 11 metres above sea level, and it consists of several islands. The city has a tropical climate, with monthly mean humidity ranging between 57-87 per cent. The annual average rainfall is 2,078 mm with 34% falling in July. The annual average temperature is 25.3°C, rising to a maximum of 34.5°C in June and minimum of 14.3°C in January. The moderating effects of the nearby sea and the fairly high amount of relative humidity in the atmosphere also restrict the variability. January is invariably the coldest month and May the warmest.

3.1.4. Bangalore

Bangalore district is located between latitude 12°58'N and longitude 77°35'E and at 916 meters above the mean sea level. It is situated at the center of the south Indian peninsula, almost equidistant from both the eastern and western coast. It is the capital city of the State of Karnataka.

The district has expanded tremendously over the years. With an area of 28.85 sq.km in 1901, the area in 1991 was 444 sq.km (44400 ha). The Bangalore Metropolitan area with a total population of 4.09 million in 1991 extends more than 1,279 sq.km of which nearly 800 sq. km constitutes the green belt area. About 444 sq. km is called the Conurbation area. The Bangalore Metropolitan area, in short Bangalore includes the Bangalore district (urban and rural) and a part of the adjoining Kolar district. The city gained the "Metropolitan" status in the 1970s. The major rivers passing through the Bangalore urban district are the Arkavathi and Dakshina Pinakini which are not perennial.

Figure 3.4 shows the map of Bangalore which is circular in shape. The commercial areas are primarily in the center of the town surrounded by the residential areas interspersed with industrial sites. The main industrial areas such as Peenya and Whitefield lie on the outskirts of the city. Parks and open spaces are seen in the city center - Cubbon Park, Lal Bagh and Palace Grounds being the main.



Geographic area = [illegible] Sq Km ([illegible] ha)
Population = 4.83 million in [illegible]

Number of manufacturing industries in 1991
Large and medium scale = 39[illegible]
Small scale = 13492

Total motor vehicles = 0.8 million in 1994/95

Power station with total installed capacity = 127 MW in 1995/96

Not to scale

Figure 3.4 BANGALORE

The climate in Bangalore is tropical monsoon plateau type. There are four seasons: winter (December to February), summer (March to May), southwest monsoon (June to September) and northeast monsoons (October to November). Typically, the annual temperature variations in the city are a minimum of 7 °C to about 37 °C. Humidity levels show a high of about 75% mean in July-October to mean 46% in March. The mean annual rainfall is 844 mm, with a mean number of rainy days being 57. June to September is the rainy season.

3.2. Demography

3.2.1. Population

Table 3.2 gives the growth of population in the four cities - Delhi, Calcutta, Mumbai and Bangalore in a comparative structure. While the annual growth of population in Delhi between 1981 and 1991 was the highest at 4.24%, the least was in Calcutta at 1.61%. In each of the four cities the rate of growth of population between 1981 and 1991 has declined, compared to the previous decade. It is estimated that currently Bangalore has around 5 million people, and the corresponding figure for Delhi and Mumbai are 11 million each and that of Calcutta around 13 million.

Projection of population for the years 2001, 2006 and 2011 have been made for each of the cities by analyzing the past growth figures in the last three decades on one side and the annual growth rate during the current and next decade with the available secondary data. Estimated projections in each city are compared with secondary data to the extent possible. Like for instance, in Delhi, the annual growth rates assumed between 1991 and 2001 is 2.5%, while in the next decade a growth rate of 1.8% is assumed. Similarly, in Calcutta and Mumbai, the assumed annual growth rate figures for the current and next decade are 1.6%, 1.4% and 1.8% and 1.6% respectively. For Bangalore, a relatively high growth rate is expected as it is an upcoming business centre particularly housing a number of computer and electronic establishments. These are 3.4% between 1991 and 2001 and 3% between 2001 and 2011 respectively. A comparative analysis of our estimated population projection figures for the four cities is given in Table 3.2.

Delhi, according to our estimate, is expected to have 12.06 million people in 2001, 13.18 million in 2006 and 14.41 million in 2011 respectively. Our estimate for 2001 compares well with a range of estimates available from secondary sources. While it may not be possible to make precise forecast, large number of studies reveal that Delhi's population will range between 12 and 14 million by 2001. According to the Conceptual Plan for Delhi 2001, through effective measures, attempts would be made to restrict the population of Delhi at a lower level of 11.2 million (*DUAC, 1986*). The Master Plan of Delhi - 2001, expects that Delhi's population may range between 12.5 and 13 million in

2001, while according to the natural growth rate of population, Delhi will have 14.4 million people by the turn of the century.

Table 3.2. Growth of population in the four cities

Year ending March	Population (million)					Index of population growth (1951 = 100)			
	Delhi	Calcutta	Mumbai	BMR	Bangalore	Delhi	Calcutta	Mumbai	Bangalore
1951	1.74	5.37	2.97	-	0.79	100	100	100	100
1961	2.66	6.62	4.15	-	1.21	152	123	140	153
1971	4.07	8.30	5.97	7.79	1.66	233	155	201	210
1981	6.22	10.11	8.24	11.02	2.92	357	188	277	370
1991	9.42	11.86	9.93	14.42	4.09	540	221	334	518
1996a/	10.66	12.84	10.86	15.70	4.83	611	239	366	612
2001b/	12.06	13.90	11.87	17.20	5.71	691	259	400	723
2006a/	13.18	14.90	12.85	18.00	6.62	756	277	433	838
2011b/	14.41	15.97	13.91	18.80	7.68	827	297	468	972
	Compound annual growth rate (%)					Decadal growth rate (%)			
1951-61	4.31	2.11	3.40	-	4.36	52.47	23.28	39.73	53.16
1961-71	4.34	2.29	3.70	-	3.21	52.91	25.38	43.86	37.19
1971-81	4.34	1.99	3.28	3.53	5.81	52.98	21.81	38.02	75.90
1981-91	4.24	1.61	1.88	2.73	3.43	51.46	17.31	20.51	40.07
1991-01c/	2.50	1.60	1.80	1.78	3.40	28.01	17.20	19.53	39.70
2001-11c/	1.80	1.40	1.60	0.89	3.00	19.53	14.92	17.20	34.39

a/ interpolated

b/ estimated

c/ assumed

Source. Population Census Reports

Calcutta is expected to have 13.9 million in 2001, 14.9 million in 2006 and 15.97 million in 2011 respectively. The Calcutta Metropolitan Development Authority (CMDA) has estimated that the likely future population of CMDA on the basis of current population growth rate shall be 15.5 million in 2001 and 18.9 million in 2011 (*CMDA, 1990*). However, with the policy of decentralized urban development in the state of West Bengal, it would be possible to check to some extent the rate of growth of population in Calcutta.

Mumbai is expected to have 11.87 million people in 2001, 12.85 million people in 2006 and 13.91 million people in 2011 respectively. These estimates compared well with the range estimates of 10.9-11.9 million in 2001 and 12.5-14 million in 2011 under low and high growth scenarios of policy interventions respectively (*WS Atkins International, 1994*). However, our estimates are lower compared to BMRDA estimates. According to

BMRDA, which has used ratio method, the population of Mumbai is 13.1 million in 2001 and 15.6 million in 2011.

Bangalore, assuming around 3.4% annual growth rate of population in the current decade (which declines marginally to 3% in 2001-2011), is expected to contain 5.71 million people in 2001, 6.62 million in 2006 and 7.68 million in 2011 respectively.

3.2.2. Density

In 1991, average population density in Delhi was 6352 persons per sq. km. with maximum population density being 16833 in the Municipal Corporation of Delhi (MCD) urban, followed by 7050 in NDMC, and least being in Delhi Cantonment area 2197 persons per sq.km. However, in rural areas of Delhi the population density is 1190 persons per sq.km (*WWF-India, 1995*).

In Calcutta, average population density during 1991 was 8594 persons per sq.km. with maximum population density being in the Municipal Corporation area (21107 persons per sq.km), 11780 persons per sq.km in Municipalities, 2878 persons per sq.km. in the Notified areas. While in the non municipal and rural areas of Calcutta together, the population density in 1991 was 3126 persons per sq.km. The population density in the Calcutta city was 23670 persons per sq.km. in 1991.

The average population density of BMR in 1991 was 3463 persons per sq.km., with suburbs having population densities ranging between 15000 and 20000 persons per sq.km. (*AIC Watson Consultants Limited, 1997*). The rest of BMR had population density figure of less than 1000 persons per sq.km. Nearly 68% of the BMR's population is concentrated in Greater Mumbai or Mumbai. The population density in CBD of Mumbai (which houses the commercial centres and many residential complexes) was around 33100 persons per sq km.

The average population density in Bangalore was 9212 persons per sq.km. according to 1991 census. It can be noticed from the four Figures 3.1 to 3.4 that the population density varies considerably across the cities. Interestingly, Greater Mumbai and the Calcutta city have high population densities, around the same level (i.e. 23000 persons per sq.km.).

3.3. Transport sector profile

All the four cities are experiencing an exponential growth in the registration of motorized vehicles since 1970/71. The growth of vehicles in each of the cities has been faster than its population. For instance, Delhi's population which was 4.07 million in 1970/71 increased to 6.22 million in 1980/81 and 9.42 million in 1990/91 indicating a more than two folds increase in the last two decades (*Census of India, 1991*). While the corresponding figures of the increase in vehicle population in Delhi accounts for 0.20 million, 0.56 million and 1.8 million respectively, which indicates more than nine times increase in the last two decades as given in Table 3.3. Similar trend is observed in Calcutta, Mumbai and Bangalore. One important feature about the growth is the explosion in the number of two wheelers and cars and autorickshaws between 1981 and 1991.

Table 3.3. Growth of registered motor vehicles

Year ending March	Delhi	Calcutta	Mumbai	Bangalore
Total number of vehicles				
1971	204078	92043	-	-
1981	557000	172323	308881	-
1991	1804490	475030	628490	576910
1995	2432320	560540	667380	797610
Compound annual growth rate (%)				
1971-81	10.56	6.47	-	-
1981-91	12.47	10.67	7 36	-
1991-95	7 75	4.22	1.51	8.44

Source: Ministry of Surface Transport, 1994

With over 2.32 million registered vehicles in Delhi as on 30th March 1995, the city has the largest vehicle population in the country even though it ranks third in the list of megacities in the country after Mumbai and Calcutta. It is interesting to note that the vehicle population of Mumbai (0.67 million), Calcutta (0.56 million) and Bangalore (0.80 million) taken together accounts for 2.03 million vehicles which is even less than the vehicle population of Delhi alone during 1994/95. It would be of also interest to note that there are only around 5 people on an average to every vehicle in Delhi, whereas there are nearly 24 persons to every vehicle in Mumbai, 45 in Calcutta (*WWF-India, 1995*).

Table 3.4 gives the change in vehicle composition in the four cities.

Table 3.4 Motor vehicle composition (%)

Mode	Delhi		Calcutta		Mumbai		Bangalore	
	1991	1995	1991	1995	1991	1995	1991	1995
2-wh	67.74	66.51	41.05	44 01	38.51	41.96	76.68	74.52
Car/Jeep	21.61	23.67	39.22	37 08	42.16	35.36	14 67	14 13
3-wh.	3.49	3.08	4 27	4.39	6.26	8.71	3.21	4.7
Taxi	0.56	0.52	4.05	3.81	5.46	6.03	0.42	0.5
Bus	1.05	1.08	2.77	2.42	1.27	1.77	1.19	1.33
Goods	5.64	5.14	8.64	8.29	6.34	6.18	3.84	4.81

Among the personal vehicles, the two wheelers (i.e., scooter and motor bikes) have become the most popular mode of personal transport in all the four cities, particularly Delhi and Bangalore. While, the dependence on cars and jeeps together are quite substantial, particularly in Calcutta and Mumbai. The share of bus is very low ranging between 1.1 to 2.8% across the four cities. The number of three wheelers (i.e., autorickshaws) is increasing rapidly in the four cities. In Delhi and Bangalore the share of taxi is only around 0.5%, relatively large share of taxis are found on the roads of Mumbai (around 6%) and Calcutta (4-5%).

The transportation network in Delhi is predominantly road-based, the role of ring railway in meeting travel demand is insignificant. Delhi has the longest road length of 1284 km. per 100 sq.km. of area, in India. The road network in the city is 22,487 km. long. Delhi has a ring road which is a major facilitator for the traffic to move in different directions. With the rapid increase in the vehicles and traffic levels, all the major traffic junctions along the ring road are congested posing serious traffic problems. Proposals to construct an integrated Mass Rapid Transit System (MRTS), with a proposed length of 144 km surface rail corridor, which would utilize the existing railway corridors in Delhi, and an underground/elevated metro rail system of 41 km. consist of two corridors the East-West (24km) and the North-South (17km) are in advanced stages.

Calcutta has a unique traffic and transportation system where the demand is catered by various modes of transport; a combination of surface transport, tram services, circular railway, metro railway and river transport services exist in the city coupled with slow moving traffic like rickshaws (both cycle and pulled by human beings) and bicycles. Even then, the problem of congestion is rather acute and all these modes are incapable to meet the travel demand in the city, as only 6-7% of the total Calcutta Municipal Corporation (CMC) area is under road. In most parts of the city, the roads are narrow and heavily encroached. CMC has a road length of 1,725 km of which 1,400 km is paved. Bituminous paved roads account for 272.73 km.

The current growth in vehicular population exceeds the potential of the existing road network in the Calcutta. Also, since the central business district areas are located in the heart of city or concentrated in a particular area the traffic flow follows on unidirectional pattern. The vehicle carrying capacity of most major roads are exhausted or over strained specially at intersections. The non-availability of space and funds for road expansion and development coupled with increasing use of personal vehicles and mixing of fast and slow moving vehicles further aggravate the problem.

The road network in BMR predominantly runs in the north-south direction due to the linear expansion of the city. Currently, traffic movements are concentrated in three main corridors i.e., western, central and eastern. There are very few continuous east-west cross routes across the Island, due to limited crossings of the railway lines and the density of development. As a result of this, there is heavy concentration of traffic along these few routes. The eastern side of the island is close to the port facilities and is congested with heavy truck traffic. The western corridor is mainly congested with private car traffic.

Apart from the road network, Mumbai is also served by the suburban rail services operating along a network of some 300 kms of electrified broad gauge provided by two zones of the Indian Railways transporting about 5.2 million suburban passengers per day on some 2000 daily electric motive unit (EMU) services. The Western Railway runs from Churchgate to Virar, and the Central Railway from Victoria Terminus to Kasara, Karjat, Bandra and Belapur in New Mumbai via the harbour line.

Like other major cities, transportation infrastructures have not kept pace with this growth and increasing the congestion and pollution in Bangalore. The main traffic corridors in the city are: Bangalore - Madras National Highway (NH-7): central to northeast; Bangalore - Hosur National Highway (NH-4). The same highway also enters the city from Tumkur: this highway passes through the city entering from the northwest and leaving it in the southeast; Bangalore - Kanakapura: central to the south of the city; Bangalore - Anekal: central to the south of the city; Bangalore - Mysore: central to the southwest of the city; Bangalore - Bellary: central to north. Apart from these there are several internal roads that have heavy traffic. The ring road (partly completed) is one of these. The Anand Rao circle, the Hudson circle, West of Chord road, Old Madras Road, Magadi roads, etc., are only a few of these.

3.4. Power sector profile

Delhi is distinct in that it is the capital city of the country and is a State in itself. It would therefore be expected that some of the areas would be given due preferential treatment in terms of power supply and establishments such as hotels etc would also be large consumers of power. With regard to climate, the city is characterised by hot and dry summers and fairly cold winters. The requirements for space conditioning would thus be expected to be much higher in case of a city like Delhi as compared to the other model cities. In terms of lifestyles also, the city is upcoming and in the past decade there has been a distinct surge of materialism. It is expected that the city would continue to use energy more and more intensively over the next few years. With these characteristics the city would be expected to be one of the most intensive power consumers, but the power plants located in the city do not seem to have upgraded their capacity in line with the growing demands. As a result of the past decade, Delhi has seen a large number of power cuts and grid failures due to low and irregular voltage.

There are three thermal power plants in Delhi that generate and supply electricity to Delhi - the Rajghat thermal power station, the Indraprastha (IP) thermal power station, and the Badarpur thermal station. The Rajghat and Indraprastha power plants are managed by DESU, which also manages 7 gas turbines, located near the Indraprastha station. Additional power requirements are met by purchases from the neighboring regions.

Table 3.5 gives the type of technologies currently being used by each power generating unit and the pollution control technologies adopted, like, use of multi cyclones (MC) or ESP for controlling particulate emissions. All the three coal based thermal plants have ESPs installed for controlling emissions of suspended particulates.

Table 3.5 Details of power generating units in Delhi

Plant	Unit	Technology	Managed by	Commissioned on	Pollution control device
Indraprastha	1	Pulverized coal	DESU	-	MC
	2	Pulverized coal	DESU	-	MC+ESP
	3	Pulverized coal	DESU	-	MC+ESP
	4	Pulverized coal	DESU	-	MC+ESP
	5	Pulverized coal	DESU	-	MC+ESP
Rajghat	1	Pulverized coal	DESU	June,1988	ESP
	2	Pulverized coal	DESU	September, 1988	ESP
	3	diesel	DESU		
Badarpur	1	Pulverized coal	NTPC	-	ESP
	2	Pulverized coal	NTPC	-	ESP
	3	Pulverized coal	NTPC	-	ESP
	4	Pulverized coal	NTPC	-	ESP
	5	Pulverized coal	NTPC	-	ESP
Indraprastha	1	Gas open cycle	DESU	May, 1986	-
	2	Gas open cycle	DESU	May, 1986	-
	3	Gas open cycle	DESU	June, 1986	-
	4	Gas open cycle	DESU	July, 1986	-
	5	Gas open cycle	DESU	August, 1986	-
	6	Gas open cycle	DESU	November, 1986	-
	7	Gas open cycle	DESU	1995/96	-

The Delhi Electricity Supply Undertaking (DESU) distributes power to all consumers within the area of jurisdiction of the MCD. It also sells power in bulk to the New Delhi Municipal Committee (NDMC) and the Delhi Cantonment Board who have licenses to distribute electricity in areas lying within their jurisdiction.

The total and plantwise capacities of all the power plants in Delhi are given in Table 3.6.

Table 3.6. Plantwise installed capacity in Delhi (MW)*

Unit	Technology	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Indraprastha (DESU)									
1	(Steam thermal - pulverized fuel)	35	30	30	30	30	30	30	30
2	(Steam thermal - pulverized fuel)	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
3	(Steam thermal - pulverized fuel)	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
4	(Steam thermal - pulverized fuel)	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
5	(Steam thermal - pulverized fuel)	60	60	60	60	60	60	60	60
Sub Total		282.5	277.5	277.5	277.5	277.5	277.5	277.5	277.5
Rajghat (DESU)									
1	(Steam thermal - pulverized fuel)	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
2	(Steam thermal - pulverized fuel)	–	67.5	67.5	67.5	67.5	67.5	67.5	67.5
3	diesel	–	–	–	14	14	14	14	14
Sub Total		67.5	135	135	149	149	149	149	149
Badarpur (NTPC)									
1		100	95	95	95	95	95	95	95
2		100	95	95	95	95	95	95	95
3		100	95	95	95	95	95	95	95
4		210	210	210	210	210	210	210	210
5		210	210	210	210	210	210	210	210
Sub Total		720	705	705	705	705	705	705	705
Indraprastha (Gas Turbine) (DESU)									
1	Gas OC (N gas/naptha)	30	30	30	30	30	30	30	30
2	Gas OC (N gas/naptha)	30	30	30	30	30	30	30	30
3	Gas OC (N gas/naptha)	30	30	30	30	30	30	30	30
4	Gas OC (N gas/naptha)	30	30	30	30	30	30	30	30
5	Gas OC (N gas/naptha)	30	30	30	30	30	30	30	30
6	Gas OC (N gas/naptha)	30	30	30	30	30	30	30 +34	30+(3* 34)
Sub Total		180	180	180	180	180	180	214	282
Total		1250	1297.5	1297.5	1311.5	1311.5	1311.5	1345.5	1413.5

Figures denote derated capacity over the years

The Indraprastha thermal power plant has 5 units all of which are managed by DESU and are steam thermal units run on pulverized coal technology. This power station has one unit of 36.6 MW, 3 units of 62.5 MW each and 1 unit of 60 MW. Haryana has a share of 62.5 MW of this capacity. All of these units have some pollution control technology associated with them

The Rajghat thermal power plant is owned by DESU. In 1985/86, the installed capacity comprised a 15 MW unit and 2 diesel run units of 9.6 MW each. The diesel units were not in use after 1985/86. In 1988/89, a 67.5 MW unit replaced the 15 MW unit. Further in 1989/90, another 67.5 MW unit was set up and the installed capacity was increased to 135 MW. Both the 67.5 MW units use pulverized coal technology and have ESPs installed. Further, Rajghat has a 15 MW set which is run on diesel. Since 1991/92, the installed capacity became 150 MW.

The Badarpur power plant has 5 units all of which use pulverized coal technology and are managed by the National Thermal Power Corporation (NTPC). Three of these units have a capacity of 100 MW each while units 4 & 5 have capacities of 210 MW each.

Delhi also has 3 gas turbines each of 30 MW capacity which were installed in 1986/87. Since 1994/95, three additional units each of 34 MW have been added to Unit 6. The installed capacity in Delhi has increased by little over 13% between 1988/89 and 1995/96.

The generation levels for each of the power plants is given in Table 3.7. The total generation in Delhi increased from 5395 GWh in 1988/89 to 7343 GWh in 1992/93, and thereafter declined to 6535 GWh in 1995/96. However, the requirement of power has been growing more rapidly than the generation by DESU and the balance power is purchased from plants located in the neighboring regions and states.

Table 3.8 gives the electricity sales figure across various categories of consumers in Delhi. The total electricity consumption in Delhi has increased at the rate of 10.3% per annum between 1988/89 and 1994/95, with electricity consumption in the non-industrial sector at 9 9% per annum.

Calcutta is highly saturated and densely populated with very little scope for further expansion. People in this city generally have simple lifestyles. The climate is humid and the use of space conditioning devices such as air conditioners is not very common. The power situation in Calcutta was among the worst in the 1970s till the Calcutta Electric Supply Corporation (CESC) set up its own generating capacity.

CESC which is a private licensee supplies most of the power requirements to Calcutta. CESC generates its own power as well as purchases power from the Damodar Valley Corporation (DVC) and the West Bengal State Electricity Board (WBSEB) for distribution within its licensed area. Since, it is not possible to disaggregate

Table 3.7. Generation in Delhi (GWh)

Unit	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Indraprastha								
1	145	171	150	118	134	-	94	-
2	47	259	316	250	393	-	346	-
3	367	353	314	397	236	-	141	-
4	264	403	235	338	331	-	239	-
5	282	185	384	375	293	-	294	-
Sub total	1105	1371	1400	1478	1386	1137	1115	1117
Rajghat								
1	0	0	-	354	-	-	419	-
2	0	0	-	230	-	-	412	-
3	0	0	0.01	0.14	0.80	-	0	-
Sub total	0	0	417	584	565	628	831	728
Badarpur								
1	*		*	645		*	609	-
2	*		*	357		*	631	-
3	1393		1568	573		1828	634	1625
4	1325		1352	1261		1187	1426	1316
5	1364		1229	1149		1425	1207	1098
Sub total	4082	3900	4149	3987	4589	4440	4508	4039
IP Gas Turbine								
1	8	82	111	154	158	-	-	-
2	48	89	124	148	138	-	-	-
3	46	935	5	0.0	37	-	-	-
4	315	75	149	206	158	-	-	-
5	40	100	20	17	174	-	-	-
6	335	69	127	153	138	-	-	-
Sub Total	209	510	538	677	803	785	601	651
Total	5395	5781	6503	6725	7343	6990	7055	6535

* added to unit 3 generation

Table 3.8. Electricity sales by consumer category in Delhi (GWh)

Year	Non industrial	Industrial	Total consumption
1988/89	3875	1234	5109
1989/90	4102	1511	5613
1990/91	4591	1802	6393
1991/92	5266	1775	7041
1992/93	5680	2004	7684
1993/94	6192	2176	8368
1994/95	6810	2371	9181

the power being supplied to CMA area from WBSEB, it has been assumed that all the generation from Bandel (WBSEB) is taken up by CESC in addition to the purchases from DVC in order to approximate the total power generated for CMA area.

As given in Table 3.9, there are 5 coal fired power generating stations and one standby station (for meeting the peak power demand) located within the boundaries of CMA area. The Titagarh, New Cossipore, Southern and Mullajore thermal plants are under CESC while Bandel is under WBSEB. Additionally, CESC also has two 20 MW turbines at Kasba which are used to meet the peak hour power demand.

Table 3.9. Details of plants in Calcutta

Unit	Technology	Managed by	Commissioned on	Pollution control device
Mulajore				
1	stoker fired	CESC	1939	MC
2	stoker fired	CESC	1940	MC
3	stoker fired	CESC	1943	MC
4	stoker fired	CESC	1950	MC
5	stoker fired	CESC	1951	MC
New Cossipore				
1	stoker fired	CESC	1949	MC
2	stoker fired	CESC	1950	MC
3	stoker fired	CESC	1963	MC
4	stoker fired	CESC	1949	MC
Titagarh				
1	pulverized coal	CESC	1983	ESP
2	pulverized coal	CESC	1984	ESP
3	pulverized coal	CESC	1985	ESP
4	pulverized coal	CESC	-	ESP
Southern				
1	pulverized coal	CESC	1990	ESP
2	pulverized coal	CESC	1991	ESP
Bandel				ESP & MC
1	pulverized coal	WBSEB	1965	ESP
2	pulverized coal	WBSEB	1965	ESP
3	pulverized coal	WBSEB	1966	ESP on 15/4/95
4	pulverized coal	WBSEB	1966	ESP on 31/3/94
5	pulverized coal	WBSEB	1983	no ESP
Kasba				
1	gas turbine	CESC	1991	-
2	gas turbine -	CESC	1991	-

The Eastern belt is rich in coal deposits and hydro resources and most of the generating capacity in the vicinity of Calcutta is coal based. The older plants have been using stoker fired technology while the more recent ones use pulverized fuel.

Mullajore and New Cossipore are very old plants and some of their units have already stopped generating power. The older units generally had multi cyclone technology for controlling particulate emissions. However, with the enforcement of stringent standards of 150 μg/mcm, multi cyclones are unable to contain emissions within limits as they cannot capture particulates which are less than 5 μm size. Therefore, all units now are shifting to the use of ESPs which are able to capture particulates upto 2 μm size and therefore able to meet the emission standards for TSP. In Calcutta, seven new units with a combined generating capacity of 585 MW have been commissioned since 1983, all of which are equipped with ESPs with a reported control efficiency of 98.7 to 99.6 percent for controlling TSP emissions.

Table 3.10 provides the total installed capacity of the power plants which are located in Calcutta. The total installed capacity of CESC in 1995/96 (605 MW) has nearly doubled since 1979/80 (310 MW). However, some units of Mullajore and New Cossipore have been shut down in the early years of this decade. On the other hand operations on additional units have commenced in the Titagarh and Southern power plants. The Kasba gas turbine unit started operating in 1991/92 and was under CESC, but with effect from July 1, 1997, this plant has been taken over by WBSEB.

Another trend which is noticeable in Calcutta is the stability in power supply which has been attained only after a long period of acute power shortages in the late 1970s. Till the late 1970s, Calcutta city did not have any power generation dedicated to the city's consumption and CESC was responsible only for distribution of power in the city. With the realization of the critical nature of power shortages in Calcutta, in the early 1980's, many new power plants were set up and CESC took over both generation as well as distribution of power for the city of Calcutta. Today, the power situation in Calcutta is fairly good and unscheduled power cuts are rare in the city. This has been made possible after the setting up of large capacity for power generation by CESC in the late 1970s.

Apart from the enhancement of capacity of power plants under CESC, technological advancement has also played an important role in Calcutta. The earlier units of Mullajore and New Cossipore used stoker fired technology which has a lower efficiency, while the units installed after the 1980's use the pulverized fuel technology. In terms of the emissions however, the stoker fired plants result in larger quantities of bottom ash and therefore lesser air pollution.

Table 3.10. Plantwise installed capacity in Calcutta (MW)*

Units	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Mulajore								
1	25.5	22	22	22	–	–	–	–
2	25.5	22	22	22	–	–	–	–
3	25.5	22	22	22	25	25	20	20
4	25.5	22	22	22	25	25	20	20
5	26	22	22	22	25	25	20	20
Sub Total	128	110	110	110	75	75	60	60
New Cossipore								
1	25	20	20	20	20	20	20	20
2	25	20	20	20	20	20	20	20
3	50	45	45	45	45	45	45	45
4	50	45	45	45	45	45	45	45
Sub Total	150	130	130	130	130	130	130	130
Titagarh								
1	60	60	60	60	60	60	60	60
2	60	60	60	60	60	60	60	60
3	60	60	60	60	60	60	60	60
4	60	60	60	60	60	60	60	60
Sub Total	240	240	240	240	240	240	240	240
Southern								
1	–	–	67.5	67.5	67.5	67.5	67.5	67.5
2	–	–	67.5	67.5	67.5	67.5	67.5	67.5
Sub Total	–	–	135	135	135	135	135	135
Kasba								
1	0	0	0	20	20	20	20	20
2	0	0	0	20	20	20	20	20
Sub Total	0	0	0	40	40	40	40	40
Bandel								
1	80	80	80	80	80	80	80	80
2	80	80	80	80	80	80	80	80
3	80	80	80	80	80	80	80	80
4	80	80	80	80	80	80	80	80
5	210	210	210	210	210	210	210	210
Sub Total	530	530	530	530	530	530	530	530
CESC Total	518	480	615	655	620	620	605	605
CMA Total	1048	1010	1145	1185	1150	1150	1135	1135

*Figures indicate derated capacity over the years

Table 3.11 provides the estimated generation by these power plants (which is taken as a proxy for demand met (availability in Calcutta) for the period 1988/89 to 1994/95.

Table 3.11. Total electricity generation from plants in Calcutta (GWh)

Plant/Years	1988/89	1991/92	1994/95
Mulajore	428	349	366
New Cossipore	669	651	706
Titagarh	1295	1364	1639
Southern	-	694	997
Kasba	-	-	17.3
Bandel	2503	2048	2304
DVC	419	341	438
CESC Total	2393	3059	3709
Calcutta Total	5314	5448	6467

During the period 1988/89 to 1994/95, the generation by CESC has increased by as much as 55% while that in CMA has grown by around 22%. An important point to note with respect to generation is the shift in technology from stoker fired to pulverized fuel technology.

Between 1988/89 and 1991/92, the generation levels from Mulajore and new Cossipore decreased due to non-availability of some of the units for part of the year. However, this loss was more than made up by generation from the Southern and Titagarh power plants.

In absence of breakup of electricity consumption by various consumer groups in CMA area, it is assumed that consumption of electricity by consumer categories in CMA is in the same proportion as that in CMC. The breakup of categorywise consumption of electricity in Calcutta is given in the Table 3.12.

Table 3.12. Electricity sales by category in Calcutta (GWh)

Sales/Years	1988/89	1991/92	1994/95
Domestic	1572	1753	2121
Commercial	877	866	995
Public lighting	76	72	74
Public waterworks	279	252	272
Industries (LT)	509	458	536
Industries (HT<1MW)	459	522	584
Industries (HT>1MW)	1509	1430	1925
Railway traction	72	64	69
Non industrial	350	199	213
Total	5703	5617	6787

The share of electricity consumption by various categories has been more or less constant between 1988/89 and 1994/95 in Calcutta. Consumption of electricity in the domestic and industrial sector have increased slightly while the share of commercial and public works has decreased marginally. While the total electricity consumption in Calcutta has increased at the rate of 3.5% per annum between 1988/89 and 1994/95, the non-industrial electricity consumption have shown a declining rate of 9.5% during the same period.

Mumbai is the main commercial centre of India. Also, the city is one of the most advanced in terms of lifestyles, but the masses at large lead a simple life. The lifestyle in the city has not seen any major change over the past decade and requirements would not be expected to change markedly in the future. Based on the coast, the city has a humid climate and does not have seasons with excessively hot or cold climate. The power supply for Mumbai has been handled by the Tata Electric Companies (TEC) which is a private licensee and has been successfully upgrading its capabilities in keeping with the growing requirements of the city. Industries, trading organizations and the suburban rail system of the city have a major advantage of having a reliable power supply system in Mumbai.

The bulk of the power supply for the city of Mumbai is provided by TEC thermal power plant. This plant is located at the Chembur-Trombay region of Mumbai. TEC also has hydro power stations at Bhira, Bhivpuri and Khopoli from where power is drawn by the TEC grid and supplied to the city of Mumbai. Additionally, the Maharashtra State Electricity Board (MSEB) supplies the balance power requirement of Mumbai. TEC maintains a grid for Mumbai and its extended suburbs. This is interconnected with the MSEB grid and the Railways' Chola grid. TEC directly supplies power to a few major industries, and also meets the entire power requirements of Bombay Electric Supply and Transport (BEST) and the Bombay Suburban Electric Supply (BSES). BSES and BEST supply, in turn to industrial (primarily small scale industries), commercial, and residential users.

Table 3.13 gives the technology details of power plants in Mumbai.

Table 3.13. Details of power plants in Mumbai (only by TEC thermal)

Name of plant							
Units	1	2	3	4	5	6	7
Type	oil/gas	oil/gas	oil/gas	coal/oil/gas	LSHS/coal/gas	LSHS/gas	Natural gas
Technology	thermal	thermal	thermal	thermal	thermal	thermal	Combined cycle
Managed by	TEC	TEC	TEC	TEC	TEC	TEC	TEC
Commissioned by	1956	1957	1960	1965	1984	1990	7/93-12/94
Pollution control device	ESP	ESP	ESP	ESP	ESP	ESP	ESP & FGD

TEC thermal plant has 7 units for power generation at Trombay. Units 1, 2 and 3 have a capacity of 62.5 MW each and can run on coal or oil. These are fairly old plants and are normally kept as standby for meeting peaking requirements. Unit 4 has a capacity of 150 MW and is also used sparingly. Units 5 & 6 are of 500 MW each and while Unit 5 can run on low sulphur high stock (LSHS), Coal or gas; Unit 6 is mainly gas based. With the commissioning of these 2 units, the power supply position was in a much better position and lower level of purchases were required from the MSEB. Unit 7 has been commissioned recently in 1994/95 and has an installed capacity of 205 MW.

In the early 1990's, it was proposed to install a 180 MW unit gas turbine combined cycle power plant to meet the essential loads of Mumbai on a continuous on-time basis and also serve as a startup power source for the 500 MW Units 5 & 6 in the event of a system shut down. Consequently, Trombay Unit 7 Steam Turbine Generator of the combined Cycle Unit was synchronized on 9th December 1994 (*TEC, 1994/95*).

With the growing awareness for protecting the environment, much attention is being paid both by the power generating companies and the pollution control boards to mitigate the environmental effects of power generation in Mumbai. The main pollutants that are released into the atmosphere are particulate matter and oxides of sulphur and nitrogen. R&D programmes are being implemented to either reduce (at-the-source technologies) or control air pollutants (end-of-pipe technologies). Most of the attention for reducing air pollution from power plants has been concentrated on SO_2 and on particulate matter The Central Pollution Board of India has formulated the Environmental Act (1986), which lays down the emission standards for thermal; power stations in addition to the standards for other industries. It calls for particulate retention systems to limit the particulate matter emissions. For keeping SO_2 emission levels within the limits prescribed in the ambient air quality standards, a minimum stack height is warranted and the installation of Flue Gas Desulphurisation (FGD) equipment for big units is required. Other pollutants like oxides of nitrogen are also produced in the process of combustion which have however been given lesser importance. The first FGD unit was installed at the Trombay Unit 5 in 1987 as desired by the Maharashtra Pollution Control Board. With a view to reduce the sulphur dioxide emission and to maintain the ambient air quality in the Trombay area, the Companies have also commissioned the second FGD Plant on Unit 5 in October 1994.

The effluents from the FGD plants and the Water treatment plant are properly treated before discharging them back into the sea, so that the marine life is not affected. The fly ash collected in the hoppers of the Electrostatic Precipitator Plant, which was previously discharged into the ash pond, is now utilized in the Flyash Aggregate Plant.

Table 3.14 gives the installed capacity of each of the units at Trombay.

Table 3.14. Installed capacity in Mumbai (MW)

Year	1	2	3	4	5	6	7	Total capacity
1988/89	62.5	62.5	62.5	150	500	-	-	837.5
1989/90	62.5	62.5	62.5	150	500	-	-	837.5
1990/91	62.5	62.5	62.5	150	500	500	-	1337.5
1991/92	62.5	62.5	62.5	150	500	500	-	1337.5
1992/93	62.5	62.5	62.5	150	500	500	-	1337.5
1993/94	62.5	62.5	62.5	150	500	500	-	1337.5
1994/95	-	-		150	500	500	205	1355
1995/96	-	-		150	500	500	205	1355
1996/97	-	-		150	500	500	205	1355

It should be noted that although the installed capacity has increased marginally between 1988/89 and 1996/97, the older units have been phased out and new units which are more efficient are producing power.

The generation levels as available and estimated in certain cases from TEC thermal plant is given in Table 3.15. The Fifteenth Electric Power survey has projected the requirements of TEC upto 2002. The generation from TEC thermal plant has been projected based on these growth rates. Unit wise generation data was available for only a few years. For the future and in some instances where data was not available, the generation from each unit has been estimated based on the average generation per day as supplied by annual reports of TEC.

Table 3.15. Generation in Mumbai by TEC (GWh)

Years	TEC thermal
1988/89	8341
1989/90	8461
1990/91	8757
1991/92	9003
1992/93	9225
1993/94	9805
1994/95	10141
1995/96	10676
1996/97	11136

The Tata Electric Companies supply power directly to major consumers - textile mills, refineries, fertilizer factories, municipal water and sewage pumping stations, large chemical and continuous process industries, light and heavy engineering plants, BARC, Ordnance Factory, Mumbai Port Trust, Railways, commercial complexes, etc. The distributing licensees in this area - BEST and BSES also purchase their entire power requirements from TECs, as mentioned earlier. The total energy distributed through this grid averages 8500 GWh per annum.

Table 3.16 presents the sales of power in Mumbai generated by TEC. Power generation by TEC for Mumbai is distributed by BEST and BSES mainly to residential, commercial and some small industrial units. TEC also supplies power directly to some of the large industries in Mumbai. Sales of power to non-industrial units in Mumbai has increased by 1.5 times between 1988/89 and 1996/97, while total sales have increased by 1.3 times during the same period.

Table 3.16. Sales of power by TEC in Mumbai (GWh)

Years	Sales	Non industrial sales
1988/89	7968	5804
1989/90	8182	6170
1990/91	8495	6491
1991/92	8732	6819
1992/93	8889	7028
1993/94	9447	7506
1994/95	9779	7813
1995/96	10303	8301
1996/97	10756	8719

The city of Bangalore is much smaller in size as compared to the other 3 cities considered. The city is an upcoming metropolis with a highly modernized city center. The city is developing as a major opportunity center for corporate entities and software development organizations. Growth in Bangalore is well planned. In terms of power supply, the city gets almost all its power requirements from the neighboring power plants connected to the grid. In the last few years, the power supply in this city has been deteriorating substantially and unscheduled power cuts are becoming common.

The present power situation in Bangalore is not good. Load-shedding (both scheduled and unscheduled) is a common feature. Bangalore does not have any major power plant (except the 127 MW Yelahanka power plant recently set up) within the city that provides indigenous power. It relies on power from Ramagundam in the neighbouring state of Andhra Pradesh and Neyveli and Kalapakkam in Tamil Nadu. In view of the non availability of any major power station within the city limits, the present study has not considered Bangalore city for analyzing energy use and the environmental impact in the power sector.

3.5. Industrial sector profile

Industrial sector is regarded as one of the major source of pollution in cities, particularly in large metropolitan cities where the industrial sector has been fast expanding due to availability of infrastructure (such as water, electricity, transportation, etc.). Delhi has the highest number of manufacturing industries as compared to the other three cities. The available industrial data with National Industrial Classification (NIC) codes 20 to 38 in the four cities has been compiled from a number of secondary sources and given in Table 3.17.

Delhi is typically a service town, it has experienced a tremendous industrial growth in the last five decades, when the industries have increased to 65540 (Table 3.17). In 1995, there were about 173 large and medium scale industries and 65,367 industries in small scale category. Among the large and medium scale industries, majority are electrical machinery, paper and paper products, printing and publishing, metal and alloy industries, metal products and parts, chemical and chemical products. In the small scale sector majority of industries include, textile products, machinery and machine tools, metal and alloys, metal products and parts, paper and paper products, printing and publishing, electrical machinery, food and food products, wood and wood products, furniture, and transport equipment. A major observation from the growth pattern of industries in Delhi is that during 1978 and 1996, the total number of industries has almost increased by three times while the increase in industrial areas to accommodate these new industries has not kept pace with the increase in industries.

At present, there are 22 industrial areas in Delhi which have been developed by various Government agencies. The Delhi Development Authority (DDA) has developed 10 industrial areas, the Delhi Administration 4, the Cooperative Industrial Societies 5, and the Delhi State Industrial Development Corporation (DSIDC) 3 industrial areas. There are about 35 non-confirming industrial areas accommodating a large number of industrial units, about which no documented information is available with the concerned departments/ authorities in Delhi.

Calcutta acts as the national centre of economic activities, and major node for transport in the eastern region. Besides the trade and commerce, Calcutta and its neighborhood developed into a leading industrial base in the eastern region of India. Calcutta had the least number of industries among the four cities with 491 large and medium and 8123 small scale industries during 1987. In the large and medium scale industries in Calcutta, majority of the industries include metal products and parts, machinery and parts, jute, hemp and mesta textiles, chemical and chemical products and cotton textiles. In the small scale industries, majority are paper and paper products, metal products and parts, machinery and machine tools, rubber, plastics, electrical machinery,

Table 3.17 Number of manufacturing industries in the four cities

NIC	Type	Delhi (1995)[1]		Calcutta (1987)[2]		Mumbai (1993)[3]	Bangalore (1990)[4]	
		Large & medium	Small scale	Large & medium	Small scale	All types	Large & medium	Small scale
20-21	Food and food products	11	3827	6	259		40	416
22	Beverages, tobacco and tobacco products	5	64		10			
23	Cotton textiles		406	27	17		22	831
24	Wool, silk and synthetic fibre textiles		2006		13			
25	Jute, hemp and mesta textiles		33	60	614			
26	Textile products	5	15166		13	531		
27	Wood & wood products, furniture & fixture		2633		448			514
28	Paper and paper products, printing, publishing	19	5662	16	1496	1075		842
29	Leather and leather products	2	1495		488			
30	Rubber, plastics, petroleum and coal products	10	4599	22	737	32		770
31	Chemical and chemical products	14	2025	51	568	532	30	350
32	Non-metallic mineral products	4	1387		176			
33	Metal and alloy industries	17	3114		244		54	550
34	Metal products and parts except machinery	17	5780	161	1034			
35	Machinery and machine tools	17	7280	115	890	3348	64	1322
36	Electrical machinery, supplies and parts	33	4032		626		81	
37	Transport equipment and parts	8	2844		187		20	
38	Other industries	11	3014	33	303	33790	79	7897
	Total	173	65367	491	8123	39308	390	13492

Sources [1] Compiled from "Study on Environment and Ecology of NCR", 1994, School of Planning and Architecture, Delhi, Compiled from "Industrial profile of Delhi, 1996", Directorate of Industries, Govt of NCT of Delhi, 53pp [2] Directorate of industries, West Bengal and "West Bengal Statistical Abstract"; [3] URBAIR Working Group I: "Mumbai City Specific Report", 1994. [4] "Bangalore Urban Industrial Directory, 1991", District Industrial Centre (Bangalore Urban District) jute, hemp and mesta textiles, chemical and chemical products, leather and leather products, wood and wood products, and metal and alloy industries. Some of these industries are often located in clusters within densely populated areas. The industrial situation in West Bengal and Calcutta Metropolitan Area has declined and stagnated over the last three decades. Since the late seventies, situation in the jute industries has been critical with mills being closed, liabilities mounting and established industrial houses moving away from the industry. The cotton textile industry, which too was one of the major traditional ones and is an important employer, is in crisis. According to the Department of Industrial Reconstruction, Govt of West Bengal, the principal factors behind the industrial sickness are: outdated plant and machinery, obsolete technology, surplus manpower, lack of professional management, non-availability of raw materials and no proper planning.

Mumbai is the biggest commercial and industrial centre of India. There were about 39,308 industries in the city during 1993 (Table 3.17). Majority of the industries include machinery and machine tools, paper and paper products, chemical and chemical products (including fertilizers) and textile products. The industrial areas are mainly concentrated in the Trombay-Chembur area, along the Eastern coast of the island and also in the Lal Bag area. Thirty two of these industries have been classified as hazardous industries.In Bangalore, there were over 390 large and medium scale industries and over 13,492 small scale industries in 1990. In the large and medium scale industries, majority include electrical machinery, metal and alloy industries, machinery and machine tools, food and food products, chemical and chemical products. In the small scale industries, majority include machinery and machine tools, cotton textiles, paper and paper products, printing and publishing, rubber, plastics, wood and wood products, food and food products.

Existence of such a large number of industries in metropolitan cities, where the population densities are growing very high, underlines the significance of the associated pollution problems which are likely to affect the public health. The pollution from industries is largely due to combustion of fuels such as coal, fuel oil, diesel oil, natural gas, etc. Therefore, it is necessary to study the profile of energy intensive industries in these cities and the resultant emissions from these industries. In this study, an attempt is made to analyze the energy consumption trends in the energy intensive industries located in the four cities under study and the associated pollution emissions.

3.6. Air quality profile

Air quality of a place can be described meaningfully with the help of ambient concentration levels of different pollutants. Concentration is a measure of the average density of pollutants usually specified in terms of pollutant mass per unit volume of air typically in units of micrograms per cubic meter ($\mu g/m^3$) or in terms of relative volume of pollutants per unit volume of air (ppm).

3.6.1. Standards

CPCB had laid down ambient air quality standards in the year, 1982. These standards are specified for three land use categories namely, residential and rural (R), industrial and mixed use (I), and sensitive (S) which include hill stations, national parks and monuments, etc. The ambient air quality standards which are based on 8-hourly average values for TSP, SO_2, NO_x and CO are given in Table 3.18.

Table 3.18. Ambient air quality standards: eight hourly average, prior to 1993 ($\mu g/m^3$)

Category	TSP	SO_2	NO_x	CO
Industrial and mixed	500	120	120	5000
Residential and rural	200	80	80	2000
Sensitive	100	30	30	1000

The air quality standards in Table 3.18 were revised and the new ambient air quality standards, which were made effective from May 1994, are given in Table 3.19 *(CPCB, 1994)*.

Table 3.19. Ambient air quality standards, effective from May 1994

Pollutant	Averaging time	Types of areas		
		Industrial	Residential	Sensitive
SO_2	Annual average	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$
	24 hours	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$
NO	Annual average	80 $\mu g/m^3$	60 $\mu g/m^3$	15 $\mu g/m^3$
	24 hours	120 $\mu g/m^3$	80 $\mu g/m^3$	30 $\mu g/m^3$
TSP	Annual average	360 $\mu g/m^3$	140 $\mu g/m^3$	70 $\mu g/m^3$
	24 hours	500 $\mu g/m^3$	200 $\mu g/m^3$	100 $\mu g/m^3$
Pb	Annual average	1.0 $\mu g/m^3$	0.75 $\mu g/m^3$	0.50 $\mu g/m^3$
	24 hours	1.5 $\mu g/m^3$	1.00 $\mu g/m^3$	0.75 $\mu g/m^3$
CO	8 hours	5 mg/m^3	2.0 mg/m^3	1.0 mg/m^3
	1 hour	10 mg/m^3	4.0 mg/m^3	2.0 mg/m^3

In the following sub-sections the air quality profile in the four cities has been examined by analyzing the trends of pollutant concentrations over the past 10 years for a number of pollutants. These include TSP, SO_2, NO_x, Pb and CO. While doing the analysis, ambient air quality data of various monitoring stations, depending on the location of the monitoring stations, were aggregated into three categories namely industrial, commercial and residential (*NEERI, 1991; CPCB, various issues*). The time series data on air quality was plotted on graphs to observe the trends in the annual average concentrations of various pollutants under study. This data was compared with the ambient air quality standards to understand the significance of the prevailing trends in the concentration levels. While comparing the results, the old ambient air quality standards (as given in Table 3.18) were used since the data used for the analysis pertain to the period 1980 to 1993. The results are discussed below for each city separately.

3.6.2. Delhi

Ambient air quality in Delhi is monitored regularly at nine locations. CPCB monitors at six locations viz., Nizamuddin (C), Ashok Vihar (I), Shahzada Bagh (I), Shahdara (I), Janakpuri (R) and Siri Fort (R), and the National Environmental Engineering Research Institute (NEERI), Nagpur, at three locations viz., Netaji Nagar (R), Najafgarh (I) and Town Hall (C). The pollutants monitored are TSP, SO_2 and NO_x. CPCB has also been monitoring Pb at six locations, and CO at I.T.O. junction/cross-roads.

Annual average (monitored) concentration values on TSP, SO_2, NO_x are analyzed for the period 1980 to 1993 (Figure 3.5)[1]. The peak values of average concentrations of TSP, SO_2 and NO_x occurred in 1987 in all the three types of areas viz., industrial, commercial and residential. Another major observation was that the average concentrations of TSP, SO_2 and NO_x were found to have been slowly stabilizing in the recent years. This could be probably due to the stringent implementation of environmental regulations, awareness amongst the industries and strict vigilance on pollution control measures by the Central and State Pollution Control Boards. Further, the sharp change in the observed maximum concentration values of SO_2 and NO_x in the post 1987 period need to be noted. In addition to these three pollutants Pb and CO data are also analyzed. Figure 3.5 also depicts the Pb emission profile in the city.

3.6.2.1. Total suspended particulate

The average concentrations of TSP in Delhi were observed to be dispersed widely with the values ranging between 200-700 $\mu g/m^3$ in the pre 1987 monitoring results and there were only three monitoring stations, one each in industrial, commercial and residential areas. The average concentrations were found to be gradually increasing and the dispersion was also shallow with the values ranging between 200-450 $\mu g/m^3$ with 9 monitoring stations spread in industrial (4), commercial (2) and residential (3) areas. In the recent years the TSP values are very stable and are around 400 $\mu g/m^3$ in all the areas. However, the

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[1] The lower and upper horizontal lines within each graph denotes permissible limit for SPM, SO_2, and NO_x in residential and mixed areas (industrial and commercial) respectively. However, for Pb, the single horizontal line denotes its permissible limit.

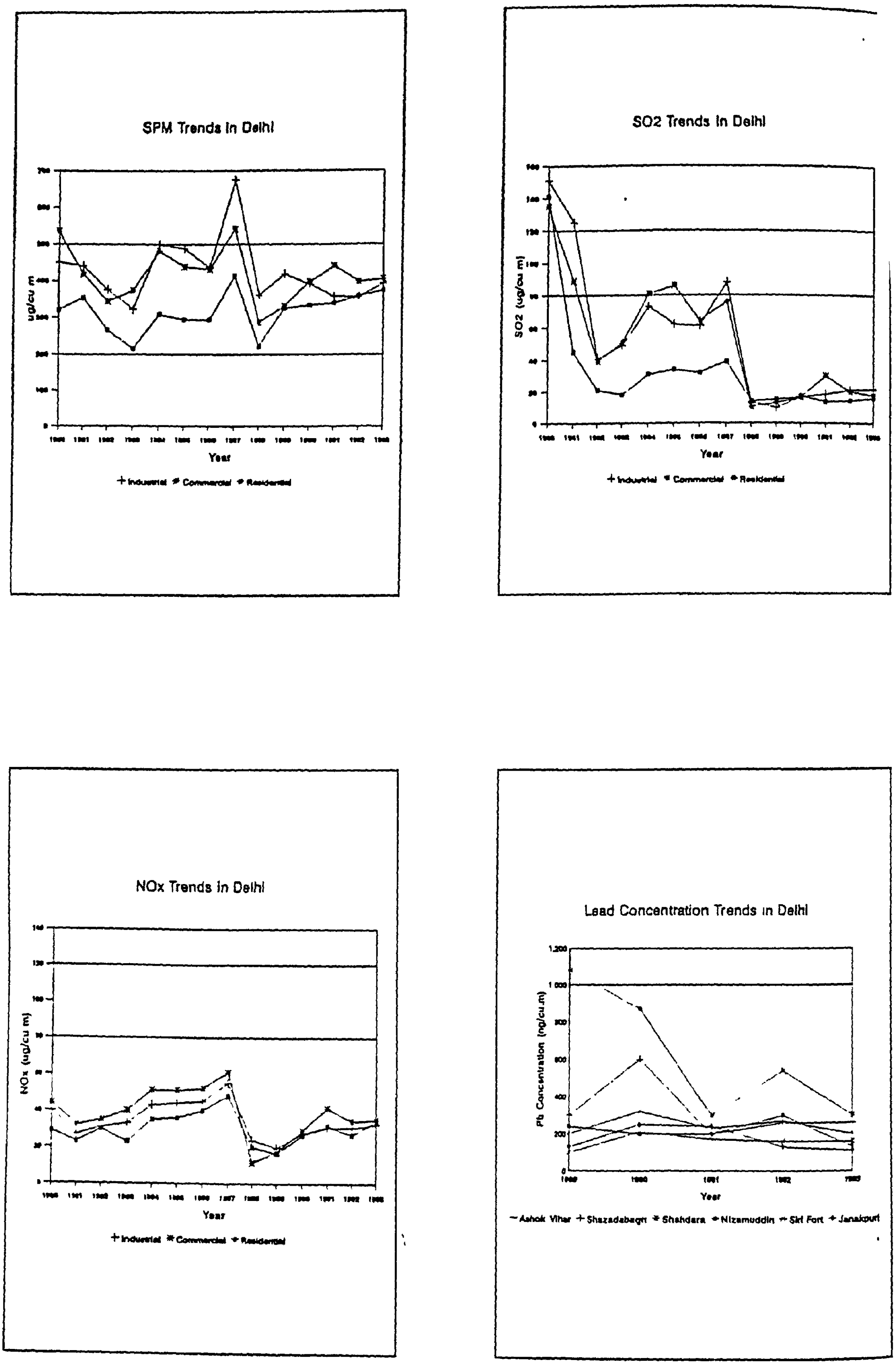

Figure 3.5. Air quality trends in Delhi

average concentrations were above permissible limits in the residential areas. Maximum values of TSP concentrations have been observed to have been widely dispersed, but the trend has been gradually increasing with the values of the order 2300 $\mu g/m^3$ during 1991-92 while the maximum values observed during '80s was ranging between 800 and 2000 $\mu g/m^3$.

An overview of the pollution status in different pockets of Delhi during 1993 reveal that the TSP levels vary between 360 and 430 $\mu g/m^3$ during summer season. The lower values are occurring over Safdarjung Air port area and the highest values are occurring over Connaught Place and Old Delhi Railway Station. The values are in the range of 400 $\mu g/m^3$ in Karol Bagh, India Gate and Nehru Place areas. During premonsoon season, the TSP levels vary between 200 $\mu g/m^3$ and 400 $\mu g/m^3$. The highest values are occurring in the Old Delhi Railway station area and the lowest values are occurring over Safdarjung Air Port area. During postmonsoon season, the TSP levels are observed to be ranging between 360 $\mu g/m^3$ and 600 $\mu g/m^3$. The highest values in this season were observed to be occurring near Punjabi Bagh (600 $\mu g/m^3$) and Connaught Place area (540 $\mu g/m^3$) and the lowest values occurring towards Malviya Nagar and Tughlakabad side. The values were observed to be high in areas inside the ring road (around 500 $\mu g/m^3$). In winter season, the TSP levels were observed to be ranging between 260 $\mu g/m^3$ and 380 $\mu g/m^3$. Higher values of the order 350-380 $\mu g/m^3$ were observed in areas like Connaught Place, Old Delhi railway station, Punjabi Bagh and Safdarjung Air Port and surroundings. Lower values of the order 280-300 $\mu g/m^3$ were observed in areas like Shahdara, Nizamuddin, Malviya Nagar/Tughlakabad and Pitampura. In short, the 8-hourly average concentration values of TSP are exceeding the ambient air quality standards (500 $\mu g/m^3$ for industrial areas; 200 $\mu g/m^3$ for residential areas and 100 $\mu g/m^3$ for sensitive areas) in many of the areas (*CPCB, 1994*).

Total TSP emissions during 1990 was around 115,700 tonnes per annum (*NEERI, 1991*) Particulate emissions are estimated to increase to 122,600 tonnes per annum by 2000. Increasing TSP emissions are attributed to industries especially the ceramic (brick) industries which are the major sources of TSP after power stations. Anthropogenic emissions are not the only source of TSP in Delhi. Natural dust storms which blow in pre-monsoon period increases the concentration of particulate considerably in the atmosphere. This natural dust remains in circulation for longer periods. Road transport (only the diesel driven vehicles) add considerably to anthropogenic TSP in Delhi.

3.6.2.2. Sulphur dioxide

The average concentrations of SO_2 in Delhi were observed to be dispersed widely and showed a decreasing trend during the period 1980-87 with the values ranging between 20-

150 $\mu g/m^3$. In the post 1987 times, the average concentrations of SO_2 were observed to be very stable in industrial, commercial and residential areas with the values ranging around 20 $\mu g/m^3$ and were well below the permissible limits. Maximum values of SO_2 concentrations were found to have been widely dispersed in the study period.

An overview of the pollution status in different pockets of Delhi during 1993 reveal that the SO_2 levels over Delhi are found to be varying between 10 and 21 $\mu g/m^3$ during summer season. The lower values occurred in areas like Safdarjung Air port and Paschim Vihar Punjabi Bagh areas. While the higher values occurred in areas near Karol Bagh and Shahadra. During premonsoon season, the SO_2 values are varying between 14 and 22 $\mu g/m^3$ over the city. In the post monsoon season, the values are observed to be very high ranging between 14 and 38 $\mu g/m^3$. The higher values are observed in the areas inside the ring road ranging between 22 and 34 $\mu g/m^3$ with the peak value of 38 $\mu g/m^3$ occurring in areas near Connaught Place and Old Delhi railway station and Shahadra and eastern parts of the city. The SO_2 values in the winter season are also observed to be considerably high ranging between 12 and 32 $\mu g/m^3$. The higher values are observed in the central parts like Connaught Place, Old Delhi railway station and extending to Punjabi Bagh and western parts of the city. The values in the eastern part of the city are also observed to be high. The southern part of the city is observed to have low concentrations.

Total anthropogenic SO_2 emissions are estimated approximately at 45,000 tonnes per annum in 1990 with a projected increase to 49,000 tonnes per annum by 2000 (*NEERI, 1991*). With the growth in the number of vehicles, SO_2 emissions from transport sector have increased and will continue to increase. Though the number of diesel driven vehicles (the major source of vehicular SO_2 emission) have increased from 16,658 in 1971 to 75,709 in 1987, the 8-hourly mean concentration of SO_2 in Delhi has been also well below the standard limit of 120 $\mu g/m^3$ during 1990 (*CPCB, 1994*).

3.6.2.3. Oxides of Nitrogen

The average concentrations of NO_x in Delhi were observed to follow an increasing trend in the pre 1987 scenario with the values gradually rising and were in the range 20-60 $\mu g/m^3$ in all the industrial, commercial and residential areas. In the post 1987 scenario, the average concentrations of NO_x were observed to again follow the increasing trend with the values ranging between 20-40 $\mu g/m^3$. During 1992/93, the values were stabilized at around 35 $\mu g/m^3$ in all the three types of areas. However, the average concentrations were well below the permissible limits in all the areas during the study period. The maximum concentrations of NO_x concentrations were found to have been gradually increasing all through the period of analysis, except for a slight fall in 1987/88, with the values touching 200 $\mu g/m^3$ in the recent years. In the last two years of observation, the maximum concentration values of NO_x were seem to be stabilizing at 160 $\mu g/m^3$ indicating the effect of pollution control regulations and vigilance by the concerned authorities and industries.

An overview of the pollution status in different pockets of Delhi during 1993 reveal that the NO_x values over Delhi are observed to be varying between 14 $\mu g/m^3$ and 34 $\mu g/m^3$ in summer season. The higher values are observed in all the eastern parts of the city such as Shahadara and northern parts of the city such as Karol Bagh, Old Delhi railway station, Delhi University, etc. Lower values are observed in north-western parts of the city including Punjabi Bagh and southern parts of the city including Safdurjung Air port. During premonsoon season, the NO_x levels are observed to be varying between 25 and 35 $\mu g/m^3$ over the city. It appears that there is no considerable variation in NO_x values over different areas. In the post monsoon season, the values are observed to be highly varying with values ranging between 26 and 53 $\mu g/m^3$. The higher values are observed in Connaught place and Old Delhi railway station areas while the rest of the areas are observed to have gradually low values. The NO_x values in the winter season are also observed to be varying highly ranging between 27 and 47 $\mu g/m^3$. The higher values are observed in the central areas including Connaught Place, India Gate, Old Delhi railway station while the remaining parts of the city are observed to have low concentrations. The 8-hourly mean concentration of NO_x in Delhi was below the permissible level in 1990.

3.6.2.4. Lead

The Pb concentrations in Delhi (observed for the period 1989-1993) were observed to be dispersed widely with the values ranging between 0.1 and 1.1 $\mu g/m^3$. In the recent years, the dispersion has narrowed down with the values ranging between 0.2-0.4 $\mu g/m^3$. However, the values were within the permissible limits at all the locations. The maximum concentration values of Pb were also observed to be decreasing.

3.6.2.5. Carbon monoxide

The average concentrations of CO in Delhi were observed to be dispersed widely with the values ranging between 1-4 ppm[2] during 1988-90 and between 2-8 ppm during 1991-93 which indicates an increasing trend in the average concentration range, but they were just below the permissible limits. The maximum concentration values of CO were found to be gradually increasing with the values some times touching the range of 10-14 ppm.

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[2] 1 ppm = 1145 $\mu g/m^3$

3.6.3. Calcutta

NEERI has analyzed pollutants emitted from different types of sources in Calcutta in late 1980s. According to NEERI, nearly 283.8 tonnes of particulate matter is emitted in Calcutta per day. The major source of such emission was from power generation units. Industries also shared 37.9% of emission of particulates. The sulphur oxide emission was recorded as 64.7 tonnes per day in the atmosphere with power generating units share being 71%, the industries share was 17.7% and the remaining share from domestic and vehicular traffic. Different types of transport emitted 15.6 tonnes of oxides of nitrogen per day out of total emission of 47.3 tonnes per day. The power sector also contributed a major share of 36.4% emission of NO_2. 176.7 tonnes of CO was recorded to be emitted per day in Calcutta out of which transportation alone emitted 138.7 tonnes. Survey also indicated that 53% hydrocarbon out of 59.1 tonnes per day was emitted from different industries in Calcutta. 31% HC emission was caused by movement of different transport vehicles. The air quality monitoring data in traffic island during 1992/93 indicated that TSP, SO_2 and NO_2 were of highest order during winter season in Calcutta city.

The ambient air quality of Calcutta Metropolitan District indicated that TSP, SO_2 and NO_2 are expected to exceed their permissible limits unless proper pollution control measures are taken at different emission sources. Another study sponsored by the West Bengal Pollution Control Board and conducted by the Centre for Study of Man and Environment (CSME) includes monitoring of ambient air quality at four stations in Calcutta between March 1992 and March 1993 (*CSME, 1995*). The study when compared with the air quality data for the years of 1978/79, to find out the major trends of variation during the last 15 years, revealed some interesting results. The following changes were apparent:

- The TSP level in 1992/93 is about 50% of that measured in 1978/79;
- The SO_2 level has also come down considerably;
- The sulphation rate is about 40% of that in 1978/79;
- The NO_x level in 1992/93 is about 5 times that of the 1978/79 level.

The possible reasons for their differences appear to be as follows:

- The higher NO_x level in 1992/93 reflects the vast increase in the number of vehicles on roads over the last 15 years. Also because of greater traffic congestion, the vehicular emissions at traffic intersections are more because of longer idling time of engines. Further a worsening of the maintenance standards of motor vehicles in the city is perhaps reflected in the enormously high values of NO_x.
- The lower TSP and particularly the significant lowering of SO_2 in ambient air concentration during 1992/93 is probably due to more effective air pollution control measures being introduced in the large industries in and around the city.

In addition to the NEERI data, the ambient air quality in Calcutta is being monitored by CPCB at three locations, namely Cassipore (I), Lal-Bazar (C) and Mandeville Garden (R). The pollutants monitored are TSP, SO_2 and NO_x. The analysis of the time series data shown in Figure 3.6 is discussed in the following subsections.

3.6.3.1. Total suspended particulate

The annual average concentrations of TSP in Calcutta, in the period prior to 1987, were observed to have been gradually decreasing in industrial and commercial areas with the values ranging between 250 and 450 $\mu g/m^3$. While the average concentration values were widely dispersed in the residential areas with the values ranging between 250 and 600 $\mu g/m^3$. In the period after 1987 to 1993, the average concentrations of TSP were found to be dispersed widely with the values ranging between 200 and 600 $\mu g/m^3$ in all the three types of areas. However, the values were within the permissible limits in the industrial and commercial areas till recently, but have exceeded the standards in 1993. The peak values of the average concentrations occurred in 1981, 1987 and 1993 in all the areas but for residential areas in 1993. On the whole, the average values in the post 1987 period were slightly lower than the ranges in the pre 1987 period except for the year 1993. The reasons for this abrupt change in the trend need to be investigated. The maximum concentrations of TSP were observed to have been relatively stable in the pre 1985 period with the values in the range of 1200 $\mu g/ m^3$ while they were found to be varying widely during the post 1985 period with the values some times touching 2600 $\mu g/m^3$ and currently are oscillating around 1000-1500 $\mu g/m^3$.

3.6.3.2. Sulphur dioxide

The average concentration values of SO_2 in Calcutta have shown a steadily decreasing trend in the pre 1987 period in the industrial and commercial areas with the values ranging between 40 and 100 $\mu g/m^3$, while the average concentrations in the residential areas were relatively stable in the pre 1987 period with the values ranging between 35-50 $\mu g/m^3$. In the post 1987 scenario, the average concentration values have shown wide dispersion in all the three types of areas with values ranging between 20 and 80 $\mu g/m^3$. However, all through the period of analysis, the average concentrations values have been well below the permissible limits for the respective categories. The maximum concentration values of SO_2 were found to have followed a decreasing trend in the pre 1986/87 period with a larger dispersion range and were gradually increasing in the post 1986/87 period with the values ranging around 300 $\mu g/m^3$ in the recent years while in the last decade the values touched 420 $\mu g/m^3$.

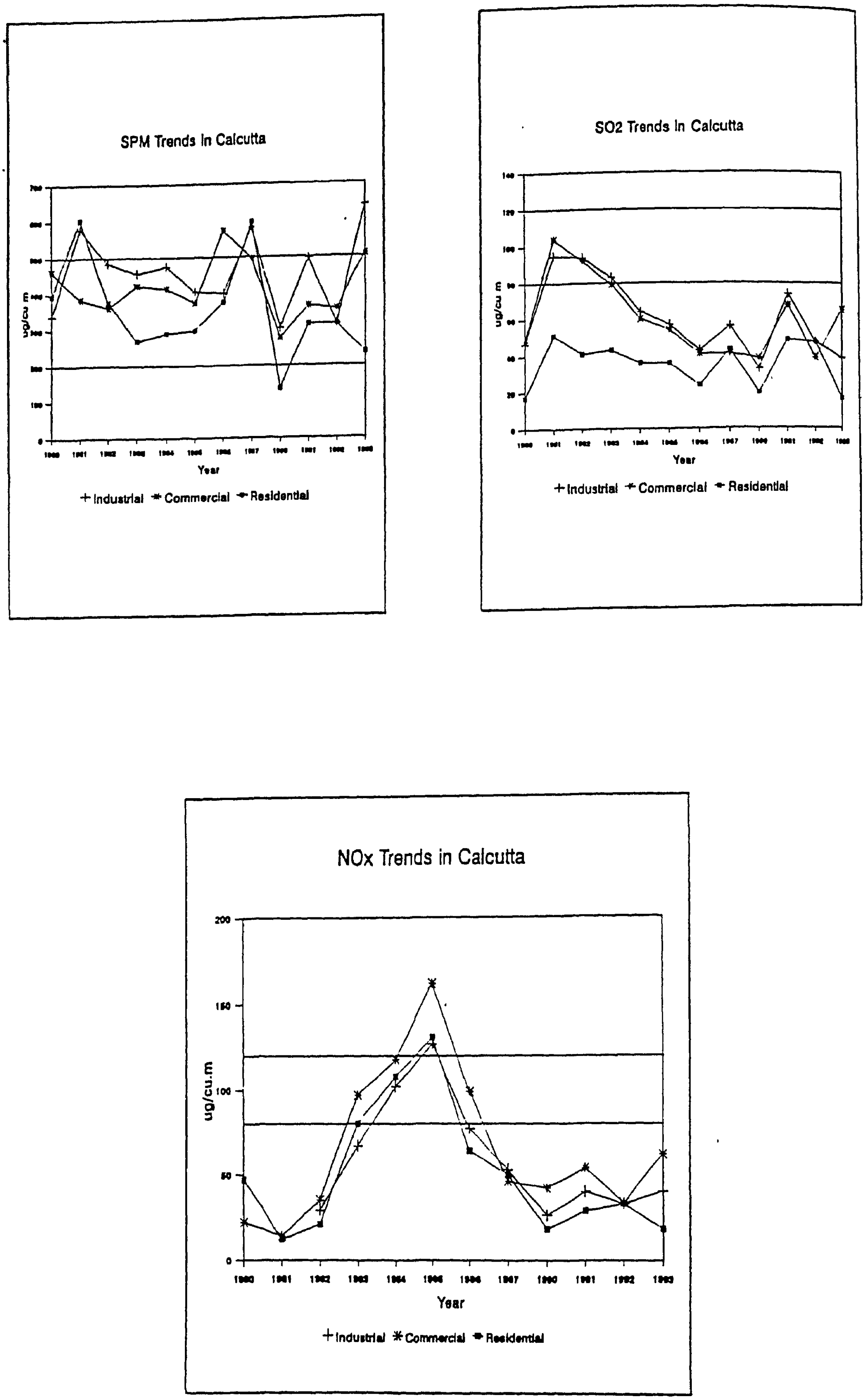

Figure 3.6. Air quality trends in Calcutta

3.6.3.3. Oxides of Nitrogen

The average concentrations of NO_x in Calcutta were found to have been very gradually increasing during the period 1980-85 with the values increasing from the range of 30-40 $\mu g/m^3$ to 130-170 $\mu g/m^3$, and the values have followed a decreasing trend till 1987 with the values decreasing to the range of 20-50 $\mu g/m^3$. During the period 1983 to 1985, the values in the residential areas were exceeding the permissible limits while in 1985 the values in the industrial and commercial areas also have exceeded the permissible limits, thus making the year as peak occurrence year. In the post 1987 period, the average concentrations of NO_x were observed to have relatively stabilized at very low ranges with little dispersion when the values have ranged between 25 and 60 $\mu g/m^3$ in the different areas. The decreased average concentration values could probably be attributed to the pollution control regulations and vigilance by the local Pollution Control Board. The maximum concentration values of NO_x were found to have been widely dispersed in the pre 1985 period with the peak occurring in 1985 followed by a decreasing trend during 1985-87 and then relatively stabilized in the early 1990s with a gradual increasing trend with the maximum concentration values ranging around 200 $\mu g/m^3$ in the recent years while in the mid 1980s the values ranged around 300-400 $\mu g/m^3$.

3.6.4. Mumbai

Ambient air quality in Mumbai has been monitored by CPCB at 3 locations namely Parel (I), Kalbadevi (C) and Bandra (R). The pollutants monitored are TSP, SO_2 and NO_x. In addition, ambient air quality is regularly monitored at 22 stations in Greater Mumbai by MCGB. The observed annual concentration data has been analyzed for the period 1980 to 1993 and presented in Figure 3.7.

3.6.4.1. Total suspended particulate

Annual average TSP concentration has increased from about 180 $\mu g/m^3$ to approximately 270 $\mu g/m^3$ between 1981 and 1990 - an increase of almost 50%. The average concentration in Mumbai were observed to have been relatively less dispersed in pre 1987 with the average concentrations ranging between 150-300 $\mu g/m^3$ in the industrial, commercial and residential ares with the residential areas having higher values exceeding the permissible limits. In post 1987, the average concentrations of TSP were relatively stable in industrial and commercial areas with the values ranging around 200 $\mu g/m^3$ while in the residential areas, the concentration values were observed to have been increasing gradually. The maximum concentrations of TSP have been increasing gradually over the study period ranging around 700 $\mu g/m^3$ in the recent years while it was around 500 $\mu g/m^3$ in the mid 1980s.

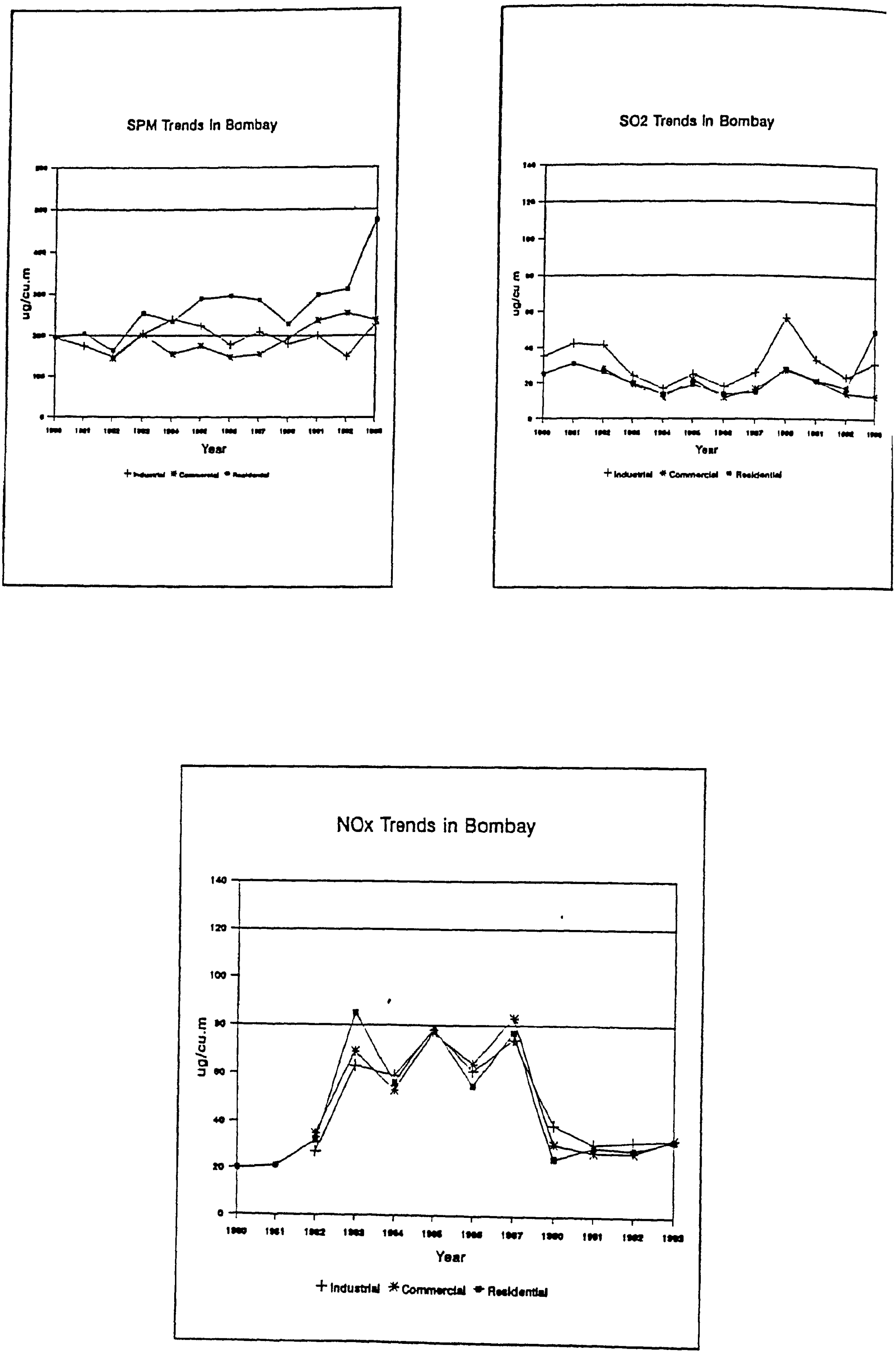

Figure 3.7. Air quality trends in Mumbai

3.6.4.2. Sulphur dioxide

The average concentration values of SO_2 in Mumbai were observed to have been gradually decreasing with very little dispersion, in the pre 1987 scenario, with the values ranging around 15-40 $\mu g/m^3$ in all the three categories of areas while values in the higher side of this range were observed in the industrial areas. In the post 1987 period, the dispersion was slightly widened with the trends continuing in the same directions, but in 1993 a sudden jump was observed in the concentrations in residential areas and the concentrations in the industrial areas was found to have been on the decreasing trend which can be attributed to the pollution control regulations by the local Pollution Control Board. The industrial areas had a peak value observed in 1990. However, during the entire period the average concentrations in all the areas were well below the permissible limits. The maximum concentrations of SO_2 were found to have followed a decreasing trend in the pre 1986 period while there has been a sudden jump in the 1987 and the maximum values remained relatively stable in the post 1986 period with the values ranging between 110 and 150 $\mu g/m^3$ while they were touching 200 $\mu g/m^3$ in the early 1980s.

3.6.4.3. Oxides of Nitrogen

The average concentrations of NO_x in Mumbai were observed to be increasing gradually in the pre 1987 period with the values ranging between 30 and 80 $\mu g/m^3$ in all the three types of areas viz., industrial, commercial and residential areas. In the post 1987 period, there has been a sudden change in the trend where the values observed were showing a very stable trend in all the three types of areas which were ranging around 35 $\mu g/m^3$ in all the areas which could probably be attributed to the stringent pollution control regulation practices and vigilance by the Pollution Control Boards. However, the values were well below the permissible standards in all the areas. The maximum concentration values of NO_x have been observed to have widely dispersed in the pre 1985 period while in the post 1985 period they followed a relatively gradual decreasing trend with the present values ranging around 130 $\mu g/m^3$ while the values have touched about 250 $\mu g/m^3$ in the mid '80s.

3.6.4.4. Lead

The average concentrations of Pb in Mumbai (for the period 1980-87) were observed to have been showing a gradually increasing trend with the values ranging between 0.25 and 1 $\mu g/m^3$, but were within the permissible limits. The maximum concentrations of Pb were found to be widely varying and on the increase with the values ranging between 3 and 8 $\mu g/m^3$.

3.6.4.5. Carbon monoxide

The average concentrations of CO in Mumbai were found to be relatively stable and were below the permissible limits. The maximum hourly concentrations of CO were found to be ranging around 2300-2900 $\mu g/m^3$.

3.6.5. Bangalore

The ambient air quality in Bangalore is measured at five locations by CPCB. These include: Graphite India (I), Amco Batteries (I), Karnataka Soaps (I), Anand Rao Circle (C) and Jayanagar Police Station (R). The pollutants monitored are TSP, SO_2, NO_x and Pb. The data from CPCB stations has been studied. Data was available only 1988 onwards as shown in Figure 3.8.

3.6.5.1. Total suspended particulate

The average concentration levels of TSP in Bangalore were observed to be gradually decreasing in all the three types of areas viz., industrial, commercial and residential, and stabilized at the 1990 levels while the concentrations in the commercial areas are slightly on the increasing trend. However, they were well below the permissible standards in all the areas. The maximum concentrations of TSP were found to have followed decreasing trend with the values when they ranged between 800-1000 $\mu g/m^3$ during 1988-90 and after a slight increase stabilized at 500 $\mu g/m^3$.

3.6.5.2. Sulphur dioxide

The average concentration values of SO_2 in Bangalore were found to have been very stable in all the three types of areas during the period 1988-91 with the values ranging between 20 and 40 $\mu g/m^3$. In the post 1991 period. the average concentrations of SO_2 have shown an increasing trend in the industrial and commercial areas while the values in the residential areas were not clearly reported. however, the average concentrations values were below the permissible limits throughout the period of observation in all the areas except for commercial ares in 1993 when the values just exceeded the permissible limits. The maximum concentration values of SO_2 were observed to have been on the increasing trend with the values ranging around 380 $\mu g/m^3$ in the recent years while they were around 150-250 $\mu g/m^3$ in the late 1980s.

3.6.5.3. Oxides of Nitrogen

The average concentration levels of NO_x were also observed to have been very stable in all the three types of areas during the period 1988-91 with the values ranging between 10 and 20 $\mu g/m^3$ and have started to be on the increasing trend in industrial and commercial areas

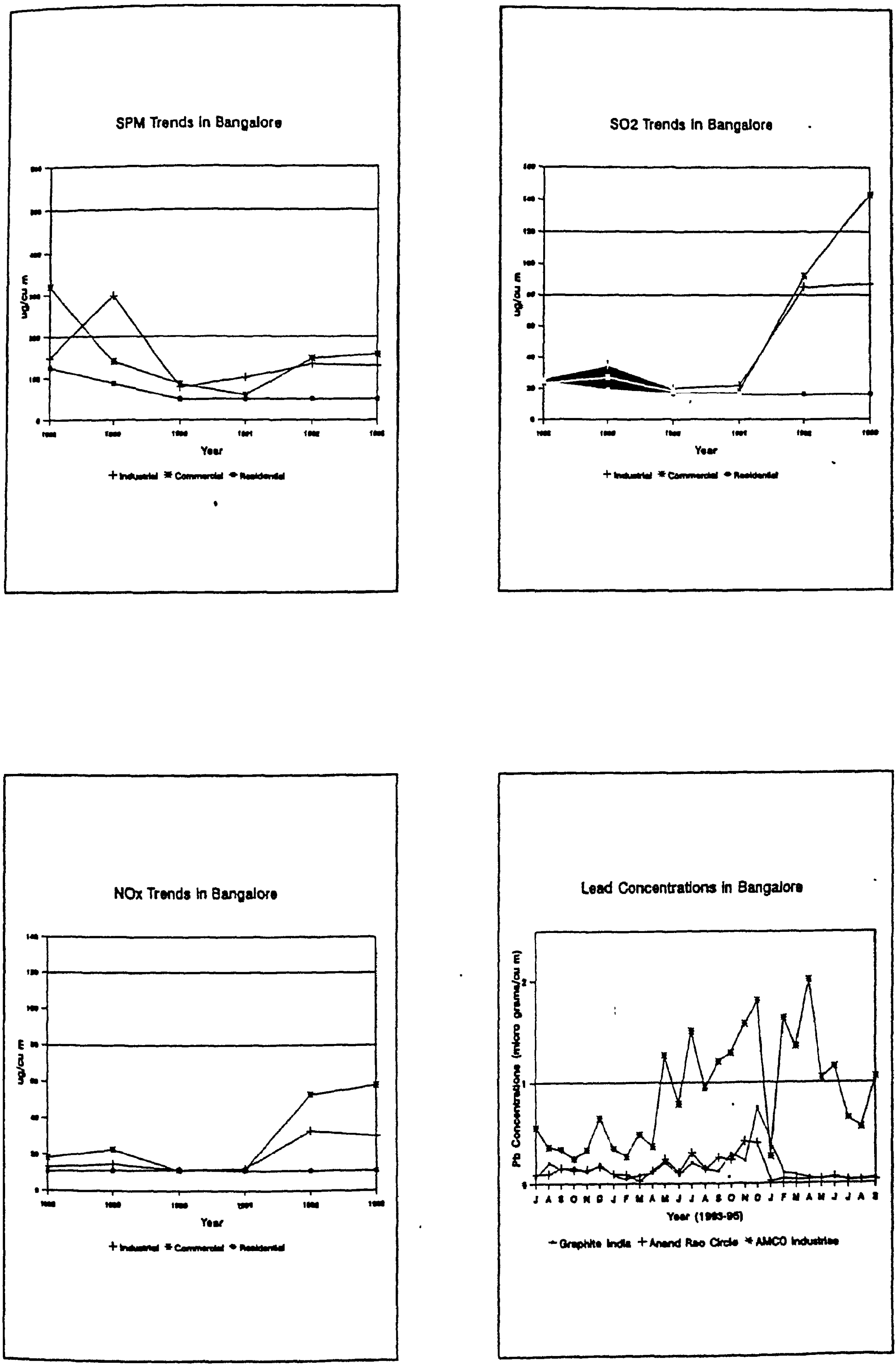

Figure 3.8. Air quality trends in Bangalore

in the post 1991 period with the values touching 40 μg/m^3 in the industrial areas and 60 μg/m^3 in the commercial areas, both showing a slightly stabilizing trend. However, the average concentration values in all the three areas were well below the permissible limits all through the study period with the available data. The maximum concentration values of NO_x were observed to have been relatively stable with little dispersion when the values have ranged between 40 and 60 μg/m^3 during the period 1988-91 while the values started showing a wide range of dispersion in the post 1991 period with the values ranging around 150-200 μg/m^3.

3.6.5.4. Lead

The Pb concentration values were found to have followed a gradually increasing trend during 1993/94 with the values ranging between 0.1 and 0.3 μg/m^3 while there has been a sudden jump at end of 1994 followed by a fall and a stable trend during 1995. The values were observed to have exceeded the permissible levels often. The maximum concentration values of Pb were found to be increasing gradually touching 2 μg/m^3 till 1994 and in 1995 has started varying widely.

The changing point for the trends in the pollutant concentrations in the year 1990 is probably a result of conscious efforts by the industries and Pollution Control Boards for reducing pollution from various sources.

Table 3.20 gives the air quality data during 1993/94 in the three monitoring stations.

Table 3.20. Ambient air quality recorded in three stations in Bangalore (1993/94)

Station	SO_2 (μg/m^3)	NO_x (μg/m^3)	TSP (μg/m^3)
Anand Rao Circle (R)	63 (60)	29 (60)	217 (140)
Amco (I)	42 (80)	15 (80)	125 (360)
Graphite India (I)	29 (80)	13 (80)	128 (360)

Note Figures in parentheses indicate the NAAQ standards (annual averages) for the pollutant in different areas - residential (R) in the case of the Anand Rao Circle and industrial (I) in the case of Amco and Graphite India.

From Table 3.20 it can be noticed that SO_2 levels in Anand Rao Circle were marginally higher than the prescribed standards, whereas TSP levels recorded were very much higher. The characteristics of this area are the tremendous mix of vehicular traffic. Three of the five roads leading to the Anand Rao Junction are from (i) the railway station (ii) the bus station and (iii) the city center - all highly congested throughout the day.

In Bangalore District as a whole, there are 237 industries generating hazardous wastes. The district alone accounts for 50 percent of the total hazardous wastes generated.

The locations identified for the disposal of hazardous wastes in the district are Sidlaghatta, Acchakadirenahally located 70 km from Bangalore city and Siddadevarabetta, 50 km from Bangalore in Magadi taluk.

The state of the urban environment in Bangalore has deteriorated drastically over the past decades. The deteriorating green belt area, the increasing urbanized areas and population are main reasons for this changing environmental situation in the city. From the industry type (considering the large and medium scale industries), most of them are non-polluting from the process point of view. They are nonetheless energy consumers - such as the engineering, electrical, etc. Major area sources in Bangalore are presently the 14 industrial estates in the city having mixed types of industrial units.

The badly planned roads and public transport system, caused a spurt in private and 2- and 3-wheeler transport modes. Visually, it can be said that the main contributor to the air pollution in the city is the transport sector; and to a lesser extent the industrial and domestic sectors. The vehicular traffic is probably the largest contributor to air pollution in the city. Vehicular growth, especially the 2-wheelers is very rapid. Badly planned city roads have enhanced the air pollution in the city. Air pollution in the city has increased. Below an analysis of this trend is given.

An air quality morbidity study by the Indian Institute of Science, shows three major pollution zones in the city, revealing a predominance in public activity such as (i) a centrally located commercial zone, (ii) a residential zone surrounding the commercial and (iii) an industrial zone located in at the outskirts. This study monitored TSP, NO_x and SO_2 in several areas in the city. The high population density (more than 40,000-120,000 persons per sq.km) areas - Cottonpet, Chamrajpet, Rajajinagar, Majestic, etc., also showed high annual mean concentrations of TSP in 1985. The same areas showed high annual mean concentrations of SO_2 and NO_x. Due to heavy traffic, and commercial activity this region shows high pollution levels. The spatial distribution of pollutants, the city was found to be divided into three zones - a centrally located 21 sq.km zone of high pollution, an outer moderately polluted zone of 119 sq.km, the outermost area consisting of industrial and farming zone of nearly 200 sq.km showed relatively less pollution.

The total morbidity (including all types of diseases) in the two most polluted areas (Chamrajpet and Cottonpet) reported was 32.26% and 38.84% respectively. Of this, the respiratory type of disease reported are 15.93% and 15.82%; cardiovascular disease for 3% and 5% respectively. This meant that out of the total morbid conditions, approximately 50% is found to be arising out of respiratory and cardiovascular diseases. One percent cancer cases were found to occur in the Cottonpet area. This morbidity data is for persons above the age of 10 years. There was only a marginal difference found between males and females (higher in a few cases).

3.7. Energy use pattern

Table 3.21 gives the time series data of different types of fuels sold in Delhi between 1990/91 and 1994/95. Average compound annual growth rate (CAGR) of different fuels sold during this period is also presented in the same table. Sales of LPG cylinders have grown considerably in the city, while that of kerosene have declined. LPG and kerosene are the two dominant domestic fuels. Rate of growth of petrol (or gasoline) has been lower compared to the high speed diesel (HSD) oil in the transport sector. Consumption of electricity went up from 6393 to 9181 GWh between 1990/91 and 1994/95. Light diesel oil (LDO) which is used in the industrial sector has declined between 1990/91 and 1994/95.

Table 3.21. Energy consumption pattern in Delhi

Fueltype	Unit	1990/91	1991/92	1992/93	1993/94	1994/95	CAGR(%) 1990-95
Gasoline	000t	344	356	363	375	408	4.36%
HSD	000t	732	747	810	840	929	6.14%
LDO	000t	66	61	41	67	64	-0.77%
LPG	000t	205	221	239	259	277	7.82%
Kerosene	000Kl	-	na	237	238	240	0.63%*
Electricity	GWh	6393	7041	7684	8368	9181	9.47%

Source: For electricity (*CEA, 1993, 1995 & 1996*) and for all others (*Govt. of NCT of Delhi 1996*).

CAGR Corresponds to 1992-95

There are three thermal power stations located within the city limits with a total installed power generation capacity of 1327 MW as on 1994/95, namely Badarpur (720 MW coal based), Indraprastha (277 MW coal based and 180 MW gas based) and Rajghat (135 MW coal based and 15 MW diesel based). While the Badarpur Power Plant is managed by the National Thermal Power Corporation (NTPC), the later two power stations are managed by DESU which has been renamed as the Delhi Vidyut Board (DVB).

Of the total electricity available in Delhi during 1995/96, only 48 per cent of power is generated in the three power stations located within the city and the rest is purchased from the neighbouring states. However, in 1990/91, over 70% of the total power available in the city came from local generation and 30% was purchased from the neighbouring states. This only indicates that growth of electricity consumption in the city is increasing at a much higher pace than the local generation potential.

Consumption of coal, fuel oil and natural gas in power plants and in industries have been analyzed separately in chapter 5. Gasoline and high speed diesel oil are used in the transportation of passenger and freight. Detailed analysis of these two fuels in the transport sector is also carried out in chapter 5. Two-wheelers, three-wheelers (auto rickshaws), taxis and some jeeps/vans/cars are run on petrol. However, in recent years, nearly 25% of cars/jeeps/taxis are run on diesel and the remaining on petrol (*ACMA, 1993*). The domestic sector consumes mainly electricity, while for cooking LPG and kerosene are used.

Table 3.22 summarizes the consumption of different fuels in Calcutta between 1980 and 1990 (*Gopalakrishnan, 1996*). On analyzing the trends of major fuels consumed in the city it is observed that the petroleum products have grown steadily during the last decade. For instance, LPG consumption has grown by around 19% annually, petrol by 10%, diesel 7.8%, kerosene 5.6%. However, total consumption of coal increased between 1980 and 1986 by 2.7% per year and then declined gradually. The consumption of coal in thermal power stations have increased at the rate of 1.7% per annum between 1980 and 1990, while its consumption in the domestic sector has declined by about 4% annually in late 1980s, possibly due to a shift to kerosene and LPG. Consumption of firewood as a domestic fuel in the city has declined in the last decade.

Table 3.22. Energy consumption pattern in Calcutta (in thousand tonnes)

Year	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	CAGR (%) 1980-90
LPG	1.27	1.25	1.59	1.91	3.08	3.14	3.78	4.41	5.35	6.10	19.05%
Kerosene	23.65	25.97	27.64	29.24	31.75	32.15	33.84	35.52	36.27	38.61	5.60%
Coal	959.74	960.64	941.68	1051.04	1074.95	1161.97	1155.50	1034.93	1079.37	975.02	0.18%
Petrol	43.82	46.06	66.07	71.49	75.34	80.02	86.16	93.54	98.42	103.99	10.08%
Diesel	257.24	289.75	319.87	345.21	406.89	430.58	401.08	429.95	495.45	505.69	7.80%
Firewood	49.28	47.82	46.36	44.89	43.44	41.98	40.88	39.06	37.60	36.14	-3.39%

In the domestic sector, coal is the principle fuel used by most urban poor living in the "bastis" and squatters settlements. It is also consumed by the families of middle income group

However, based on the statistics provided by the Directorate of Consumer Goods, the allotment of coal in the residential sector has declined from 70175 MT in 1990/91 to 11752 MT in 1994/95. The people living in the "bastis" and squatters settlements are supplementing their coal requirement by simply collecting fuel like firewood, or coal residue or buying "gool" and possibly buying coal from unlicensed dealers.

Supply of LPG has been increasing at a rate of approximately 6% each year. It is mainly used by the high and middle income category households. Based on fuel consumption data for 1994, it is estimated that nearly 50% of the population (or about 83% of the HIG, MIG and LIG) within CMC are using LPG for cooking.

The allotment of Kerosene oil has remained fairly constant over the years with an annual increase of about 1%. It is primarily used as a standby cooking fuel.

Substituting use of coal with less polluting town gas by the Greater Calcutta Gas Supply Corporation (CGSC) has initiated a project to market town gas to potential industrial customers primarily in Howrah. CGSC has the capacity to provide 30 million cubic feet per day (MCFD)[3] for town gas which will come from Dankuni (20 MCFD) and from Durgapur (10 MCFD). According to their market research, town gas could be a viable option for steel re-rolling, ceramic and pottery, glass, battery, paper and board industries. Successful conversion to town gas is contingent upon:

- Having proven technology of converting coal, fuel oil and electric furnaces to burn town gas.
- Ensuring uninterrupted supply of town gas
- Tariff structure, subsidies or regulatory interventions that would encourage industries to switch from coal/oil to town gas

As regards to the power distribution system is concerned, CESC is responsible for supplying power to the Calcutta city. There are 5 coal-fire power generating stations and one diesel based standby station (for meeting peak power demand) located within CMA area which are managed by CESC. The total availability of electricity in CMA during 1994/95 was 6467 GWh. Of this total availability, nearly 57% was generated by CESC and the rest was purchased from WBSEB (37%) and DVC (6%).

Table 3.23 gives the consumption of petroleum products in Greater Mumbai from 1985 to 1993 During this period, LPG, kerosene, HSD, LSHS consumption increased by 2.5%, 1.2%, 4.9% and 7.5% per annum respectively. While the consumption of gasoline, furnace oil and LDO decreased annually by 0.5%, 4.5%, 12% respectively. Due to non availability data on LSHS consumption in the TATA power plant in 1992/93, total consumption of LSHS is not presented in Table 3.23.

Data on total coal consumption in Greater Mumbai is not available beyond 1985/86 Coal consumption in 1985/86 was 2.12 million metric tons, with sulfur content of 0.5% and ash content of 12%.

Power supply in BMR is catered by TEC. TEC are responsible for generation of power and its distribution in the city. Demand for any additional power in the city is met by TEC by purchasing power from MSEB. TEC has six thermal units located at the Chembur-Trombay area in BMR with a total installed capacity of 1355 MW. Detailed analysis of type of coal, oil and gas consumed in these six units of TEC, and generation of power are provided in chapter 5. Consumption of electricity in Greater Mumbai has grown at the rate of 3.7% per annum - from 7591 GWh in 1985/86 to 9447 GWh in 1992/93

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[3] one MCFD of gas is roughly equivalent to 20 MT/Day of coal.

(Table 3.23).

Table 3.23. Energy consumption pattern in Greater Mumbai

Energy source	Unit	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1992/93	CAGR(%) 1985-93
LPG	10^6 l	201	202	204	213	213	214	233	2.49%
Kerosene	10^6 l	447	436	430	438	448	471	480	1.19%
HSD	10^6 l	438	469	508	529	551	560	583	4.88%
Gasoline	10^6 l	287	300	314	330	345	362	279	-0.47%
Furnace oil	10^6 l	403	300	367	397	298	299	306	-4.49%
LSHS	10^6 l	527	549	408	612	616	755	na	7.46%
LDO	10^6 l	99	99	118	118	115	108	46	-11.99%
Electricity	GWh	-	-	-	7968	8182	8495	8732	3.09%

Note: For electricity data pertains to the Bombay Metropolitan Region only by TEC, and CAGR for 1988-93.

The total energy consumption in all the sectors put together was 30336 TJ (terra Joule) in 1986/87. Of this total energy, the relative shares of the sectors are as follows: domestic 30%, industry 33%, transport 20% and others about 18% (Table 3.24).

Table 3.24. Sectoral energy use in Bangalore during 1986/87 (TJ)

Fuel type	Domestic	Industry	Transport	Others	Total
LPG	845	95	0	195	1135
Kerosene	4802	400	0	0	5202
Coal	0	1690	346	0	2036
FO	0	2517	0	0	2517
MS	0	0	3815	0	3815
HSD	0	1421	1853	4747	8021
LDO	0	573	0	0	573
Electricity	3334	3231	0	472	7037
Total	8981	9927	6014	5414	30336

Note The value 0 indicates no consumption of the fuel and/or negligible consumption in comparison with the other fuels.

Source Sudhakara Reddy, 1990

The present power situation in the city is not good. Load-shedding (both scheduled and unscheduled) is a common feature. This situation is the same for the State as a whole, although the total energy generated in the generating stations within the State during 1993 94 was 14,284.94 GWh as against 12,762.32 GWh in the previous year (an increase of 11.93%). The Karnataka Electricity Board (KEB) purchased 16,798.947 GWh of energy out of which Karnataka Power Corporation (KPC) contributed 13,268.461 GWh and the remaining 3,530.486 GWh from the neighbouring states. 14,044.320 GWh of energy were sold to the consumers within the state, as against 12,957.28 GWh sold during the previous year, recording an increase in sale by 8.39% (*Karnataka Electricity Board, 1993/94*).

Bangalore does not have any major power plant (except the 127 MW Yelahanka power plant recently set up) within the city that provides indigenous power. It relies on power from Ramagundam in AP, Neyveli and Kalpakkam in TN.

3.8. Environmental impacts of energy production and consumption

The combustion of fossil fuels for power generation, in motor vehicles, in industrial processes are the principal source of air pollutant emissions in Delhi. The Central Pollution Control Board has estimated that nearly 2000 metric tonnes of pollutants (which includes CO, SO_2, NO_x, HC and TSP) were emitted daily in Delhi during 1993 (*CPCB, 1993/94*). Emission loading in the city from various sectors have been increasing over time. Particularly the share of transport sector has been fast increasing which currently accounts for nearly two-thirds of the total emissions in the city, followed by industries around 29% (Table 3.25).

Table 3.25. Trends in sectoral share of emissions in Delhi

Sector	1970/71	1980/81	1990/91
Industry	56%	40%	29%
Transport	23%	42%	63%
Domestic	21%	18%	8%

Estimated emission of Carbon monoxide (CO) in 1990/91 was 1063 metric tonnes followed by NO_2 323 tonnes, HC 320 tonnes, SO_2 179 tonnes and TSP 138 tonnes (*CPCB, 1993/94*).

Table 3.26 summarizes the estimated pollution emissions from various sectors. Vehicular traffic is the main source of CO, NO_x and Pb emissions which have increased significantly (owing to the increase in vehicular population). While thermal power stations and industries contribute to TSP, SO_2 and NO_x emissions.

Table 3.26. Sectoral emissions in Delhi (tonnes/day)

Pollutant	Transport	Power	Industries	Domestic	All
TSP	13 (10%)	50 (37%)	60 (44%)	12 (9%)	138 (100%)
SO_2	11 (6%)	121 (68%)	35 (20%)	12 (6%)	179 (100%)
NOx	157 (49%)	143 (44%)	20 (6%)	3 (1%)	323 (100%)
CO	810 (76%)	8 (1%)	128 (12%)	117 (11%)	1063 (100%)
HC	310 (97%)	2 (<1%)	6 (2%)	2 (<1%)	320 (100%)

Source CPCB, 1993/94

During 1993, more than 1300 metric tonnes of pollutants were emitted by the vehicles plying in Delhi. This is more than half of what was emitted in 1987 (870 metric tonnes). Two and three wheeled petrol vehicles constitute over 70% of the total vehicles registered in Delhi (over 90% of these vehicles have two stroke engines which are highly inefficient) are one of the major sources of air pollution in Delhi. Diesel driven vehicles constitute about 6% of the registered vehicles and contribute about 19% of the total vehicular emissions.

According to CPCB, the three thermal power plants in Delhi, viz., Badarpur, Indraprastha and Rajghat emitted about 302 metric tonnes of pollutant every day in 1993, which is almost one-third of the daily emission in 1987. With improvement in the efficiency of electrostatic precipitators installed in these plants, the TSP emissions have reduced considerably - from 720 metric tonnes per day in 1987 to only 50 metric tonnes in 1993.

The main sources of air pollution from industries located in Delhi in 1993 were, one chemical, one cement, 40 hot mix plants, and about 10,000 other types of industries. Nearly 240 metric tonnes of pollutants were emitted daily from industries in Delhi, which accounts for 12% of the total emissions. With the introduction of Prevention and Control of Pollution Act 1981, over 390 large and medium size industries in Delhi have installed pollution control devices.

The high level of coal consumption in power stations and that of petrol and diesel in the transport sector have led to significant emissions loading of critical pollutants. The total pollution load in the city has increased from about 224,000 tonnes in 1980/81 to 286,000 tonnes in 1989/90 (Table 3.27).

Table 3.27. Annual emission in Calcutta (thousand tonnes)

Year	TSP	CO	HC	NO_x	SO_2	Pb	Total
1980/81	74.93	69.31	27.36	20.81	31.64	0.009	224
1983/84	78.30	86.35	31.95	25.18	36.47	0.016	258
1986/87	82.07	98.51	35.71	28.26	40.44	0.021	285
1989/90	75.67	100.36	37.72	31.18	41.21	0.027	286

Source. Gopalakrishnan, 1997

In 1980/81, annual total emissions from the industrial sector (thermal power production and other manufacturing industries) had the highest share at 62%, followed by the transport sector at 22% and the domestic sector at 15%. Over the decade, the emissions from the transport sector have grown at a faster rate, thereby accounting for a larger share of 38.5% in 1989/90 as against 53.8% of industry and 7.7% of domestic emissions. The rate of increase of transport sector emissions is such that inspite of decline in emissions in absolute units in the industries and domestic sector, the pollution load of the city as a whole has increased.

The working groups of the URBAIR project decided to use the WHO/EPA emission factors for estimating emission loading from various sources for Mumbai (*World Bank, 1996*). A number of sources contribute emission of TSP, including PM_{10} (particulate matter of 10 microns or less), SO_2 and NO_x in the city as given in Table 3.28.

Table 3.28. Source contribution to emissions in Greater Mumbai, 1992

	TATA thermal power plant	Transport		Resuspension	Industry	Domestic	Wood	Marine	Refuse domestic
		Gasoline	Diesel			Kerosene	Burning		
TSP	6%	5%	9%	40%	7%		17%	2%	14%
PM	10%	8%	16%	16%	10%		14%	3%	23%
SO	33%	1%	4%	-	48%	2%	-	12%	-
NO	30%	18%	34%	-	11%	4%	-	3%	-

Source World Bank, 1996.

Daily emission loading of these pollutants were 89, 44, 216 and 71 metric tonnes respectively during 1992/93. Road traffic, particularly resuspension of road dust (40%), wood burning (17%), domestic refuse burning (14%) and furnace oil use in industry (7%) are the largest sources of TSP emissions. While, refuse burning (23%), resuspension of road dust (16%), vehicle exhaust from diesel trucks (16%) were dominant source for PM_{10} emissions. Emissions of SO_2 were calculated on the basis of 4% sulphur content in fuel oil, 1.8% LDO, 1% each in LSHS and HSD, 0.25% in kerosene and 0.2-0.25% in gasoline with different octane rating. Industries (48%) and TEC thermal power plant (33%) were the main contributor of SO_2 emission. As far as NO_x emission is concerned, vehicle exhaust especially from diesel trucks contribute as high as 34%, and TEC thermal power plant 30%.

The nature and magnitude of vehicular pollution load was attempted by the Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore in 1995 (*IIS, 1995*). However, no studies were found which estimated the emission load in the city from the other sectors. With this limited data, it was estimated that nearly 1145 metric tonnes of vehicular pollution load were emitted daily in 1994/95. The two and three wheelers accounted for 57% of the total load and the four wheelers accounted for 30% emission loading. The major pollutants from the transport sector were CO (63.7%), HC (24.8%), NO_x (9.95%), TSP (0.9%) and SO_2 (0.67%) respectively. The exhaust emissions for various vehicles show maximum emissions from heavy duty diesel powered vehicles followed by light duty diesel powered vehicles and motor cycles. However, the percentage pollution load of two wheelers is the highest as they constitute 75% of all the vehicles on Bangalore roads. Over 85% of the total vehicular pollution load was due to petrol driven vehicles and the remaining 15% due to diesel driven vehicles.

Other than vehicles, industries, open cooking, garbage, open sewerage, generator sets etc. also contribute to air pollution. However, emission contribution from these sources in the city are not yet available.

CHAPTER 4

Framework for analysis

This chapter gives the methodological framework used for analyzing the environmental implications of energy use in transport, power and manufacturing industrial sector located in each of the four cities - Delhi, Calcutta, Mumbai and Bangalore. The proposed framework is flexible enough and can be easily applied to a spectrum of large Asian cities.

4.1. Transport sector

4.1.1. Energy demand and emissions using LEAP model

A simple model of passenger and freight transport for Indian cities have been developed using a computer based software called - Long Range Energy Alternatives Planning (LEAP) and the associated Environmental Database (EDB) system - to estimate the energy demand and emission levels under different policy scenarios.

4.1.1.1. What is LEAP?

LEAP is a computer based accounting and simulation tool designed to assist policy makers in evaluating energy policies and developing sound, sustainable energy plans (*SEI-B, 1993*) LEAP has been developed by the Stockholm Environment Institute - Boston (SEI-B) The Environment Database has been developed by SEI-B with additional support from the United Nations Environment Programme (UNEP), and is a joint UNEP/SEI activity.

The central concept of LEAP is an end-use driven *scenario analysis*. To start with, current energy situation and estimated future changes based on expected or likely plans and growth trajectories are developed in LEAP. This "business-as-usual" (BAU) scenario is referred to as the *base case*. Then, one or more *policy scenarios* with alternative assumptions about future developments are developed. Under scenario features, any number of "what if" questions can be analyzed. For instance, in addressing urban transport policy scenarios, the type of questions could be - what if more efficient technologies are introduced? what if clean fuels are introduced? What if mass transport facilities are introduced?

LEAP system therefore, helps in analyzing the current energy scene and simulate alternative energy futures along with environmental emissions under a range of user-defined assumptions and arrive at strategies that best address environmental and energy problems.

Within the LEAP framework, the *Energy Scenarios* programme provides a disaggregated, end-use approach to analyze energy requirements. First, data are assembled in a hierarchical format based on four levels: *Sector, Subsector, End-use* and *Device*. Next, data on average energy requirements (*Energy Intensity*) of each Device (at the fourth level) are required at the final step for estimating the energy requirements at the sectoral/subsectoral/end-use levels under alternative scenarios. On the other hand, the environment programme are based on emission coefficients contained in EDB. EDB is linked to the *Energy Scenarios* programme to analyze the environmental impacts of energy alternatives over the time horizon considered.

Under each of the four levels, five reference years (with first year as the base year) can be chosen for which energy demand and resultant emissions are evaluated. Apart from the base year data in LEAP energy module, it also requires data for any of the future years (estimated exogenously) and then the LEAP framework can estimate energy demand and emissions by using interpolation/extrapolation method. Alternatively, along with the base year data in LEAP energy module, growth factor can be specified to estimate energy demand and emissions for the remaining reference years. Former method is used in this study for estimating energy demand and emissions under alternative scenarios.

4.1.1.2. LEAP framework

The specific model for estimating energy demand and emissions by the transport sector in the four cities Delhi, Calcutta, Mumbai and Bangalore using LEAP framework is described in this section. The four levels are illustrated by a schematic diagram in Figure 4.1. The reference years considered for this study are 1990/91 (base year), 1995/96, 2000/01, 2005/06 and 2010/11.

For the Energy Scenarios programme of LEAP, the data requirement at the four levels include:

Sector:	Total passenger and freight travel demand in the four cities estimated using Eq.(4.2) described later. Passenger and freight travel demand are expressed in billion (10^9) passenger kilometre (bpkm) and billion tonne kilometre (btkm) respectively.
Subsector:	Percent share of total passenger and freight travel demand catered by different modes estimated using Eq.(4.2).
End-use:	Percent share of total travel demand catered by different technologies under a given mode. In other words, disaggregation of major modes according to the range of technologies and alternate fuels.
Device:	Inverse of average occupancy (load) level for passenger (freight) vehicles. Inverse of occupancy level of passenger vehicles is also the vehicle space per passenger.

Under Energy Intensity, fuel efficiency norms associated with each type of vehicle at the fourth level (Device), expressed in kilograms of oil equivalent per kilometre

Energy demand scenarios
Branch data

Sector	Sub-sector	End-use	Device	Energy intensity
Passenger travel demand	scooter/motorcycle	2-wh: 2 stroke	2 stroke	gasoline
		2-wh. 4 stroke	4 stroke	gasoline
	autorickshaw	3-wh· conventional	conventional	leaded gasoline
		3-wh· propane	propane	propane
		3-wh battery operated	BOV	electricity
	car/ jeep	pre-1984 gasoline model	pre-1984	leaded gasoline
		post-1984 gasoline model	post-1984	leaded gasoline
		with vatalytic convertor	catalytic convertor	unleaded gasoline
		diesel	diesel	diesel
		compressed natural gas	CNG	CNG
		battery operated	BOV	BOV
	taxi	gasoline	gasoline	leaded gasoline
		diesel	diesel	diesel
		compressed natural gas	CNG	CNG
	bus	conventional diesel	diesel	diesel
		compressed natural gas	CNG	CNG
		battery operated	BOV	BOV
Freight travel demand	light commercial vehicle	lcv	lcv	diesel
	heavy commercial vehicle	hcv	hvc	diesel

Figure 4.1. LEAP schematic diagram for urban transport

(kgoe/km) is compiled within the LEAP framework. In other words, Eq.(4.3) described later, is used to compile database in the energy module of LEAP to estimate fuel demand by various modes and technologies.

Whereas, Emission Coefficients - expressed in mass of pollutants emitted per unit of fuel burnt (emission factors) are compiled for the six major pollutants viz., CO, HC, NO_x, SO_2, TSP and Pb under typical Indian urban driving cycles[1] in the EDB structure of LEAP. Eq. (4.4) described later, is used for compiling database in the EDB module of LEAP to estimate emissions by different modes and their respective technologies.

A linkage is then developed between the device level in both energy scenarios program and EDB. LEAP model is then run to estimate the level of energy demand and emission level of different pollutants, in a range of defined scenarios described later.

4.1.1.3. Growth of vehicles and travel demand

The following equations are used for estimating growth of motorized vehicles in the four cities and the passenger and freight travel demand for the five reference years.

Number of vehicles registered from 1984/85 to 1994/95 are regressed with time in each of the four cities to extrapolate their growth. The functional form of the linear regression is given in Eq.(4.1).

$$V_{kt} = a + b_k t \qquad k = 1,2,\ldots\ldots,6 \tag{4.1}$$

where. V_{tk} denotes the number of registered vehicles of type (or mode) k in time period t [t= (n+1) - 1984/85, with n = reference year]. The coefficients in Eq.(4.1) is obtained by the ordinary least square method. Index k in Eq.(4.1) denotes mode of transport. Data on registration of vehicles are available for five types of passenger modes and one freight mode. These include two-wheeler (scooter, motor-bike and moped), three-wheeler (autorickshaw), car and jeep, taxi, bus, and the goods vehicle.

Passenger (freight) travel demand catered by different modes in year t is given by Eq.(4.2).

$$D_t = V_{kt} \times U_k \times O_k \qquad k = 1,2,\ldots\ldots,6 \tag{4.2}$$

where, D denotes passenger (freight) travel demand expressed in passenger kilometre (tonne kilometre), V denotes the registered number of motorized passenger (freight) vehicles estimated Eq.(4.1), U denotes average vehicle utilization and O denotes the average occupancy (load) of vehicle. Total passenger (freight) travel demand is the aggregation of travel demand across different modes.

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[1] A typical urban driving cycle is a four-cycle mode and consists of *idling, acceleration, cruising* and *deceleration*

The distribution of six major road based transportation modes denoted by index k above are further disaggregated according to the types of technologies denoted by index i. Technologies include new and efficient technologies including end of pipe or control technologies as well as the use alternate fuels in a specific technology. Following range of technologies and type of alternate fuels have either been plying on the road or are likely to be introduced in near future in the four cities.

- Scooter/motorcycle/moped: Two and four stroke gasoline technologies
- Autorickshaw: Two stroke gasoline, propane and battery operated technologies
- Car/jeep: Pre-1984 and post-1984 gasoline without catalytic convertors, post-1994 gasoline with catalytic convertors, diesel, CNG and battery operated technologies
- Taxi: gasoline, diesel and CNG technologies
- Bus: diesel bus, CNG, battery operated technologies
- Goods: light commercial or heavy commercial vehicles.

4.1.1.4. Energy demand

Energy demand by a given technology i in year t is estimated by using Eq.(4.3).

$$F_{it} = D_t \text{ x } S_{it} \text{ x } O_{it}^{-1} \text{ x } E_i \qquad i = 1,2,.....,n \qquad (4.3)$$

where, F denotes annual fuel demand expressed in kilograms of oil equivalent (kgoe). S denotes the percentage share of total passenger and freight travel demand by various modes. E denotes the operating energy intensity[2] expressed in kgoe/pkm or kgoe/tkm depending upon the passenger or goods vehicles. Total energy demand is obtained by aggregating fuel demand across different modes and their respective technologies.

4.1.1.5. Emissions

Annual emissions of six pollutants (viz., CO, HC, NO_x, SO_2, TSP and Pb) denoted by j in year t are estimated by using Eq.(4.4).

$$P_{ijt} = F_{it} \text{ x } EF_{ijt} \qquad i = 1,2,.....,n \text{ and } j =1,2,.....,6 \qquad (4.4)$$

where, P denotes emissions expressed in tonnes and EF denotes emission factors expressed in grams per litre of fuel burnt (g/l). Total annual emissions of a pollutant can be obtained by aggregating the emission values across different modes and technology.

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[2] The operating energy intensity represents the fuel efficiency of different technologies. It measures the amount of energy needed by a specific technology to move 1 person over 1 km by a given mode (*Government of India 1980*)

4.1.2. Scenario construction and assumptions using LEAP

Three scenarios are considered to study the impact of different urban transport policy initiatives that would reduce total energy requirement and emissions in the road based passenger transportation in the four cities compared to the business-as-usual (BAU) scenario. These scenarios are defined below:

4.1.2.1. Business-as-usual or base case

This scenario assumes that the present trends of growth in registration of vehicles in each of the four cities will continue, while the present fuel efficiency norms, occupancy level and vehicle utilization pattern for different modes will remain unchanged in future.

4.1.2.2. Alternative scenarios to contain energy demand and emissions

Scenario 1: Strengthening of public buses

This scenario examines the impact of strengthening of public buses on energy demand and emissions.

Scenario 2. Introduction of efficient technology and cleaner fuel

This scenario examines the impact of introducing the following technological options and cleaner fuel - in a phased manner between 2001 and 2011 - on energy demand and emissions.

(a) Promote 4-stroke engines: For two-wheelers, conversion to 4-stroke engines on an average result in a 46% fuel economy improvement, and a reduction in HC emissions by a factor of at least 5 times (Table 5.7). This is an option for new vehicles and payback to the consumer occurs in 2 years or less at current prices. In view of this, the widely prevalent two-wheeler technology of a 2-stroke cycle engine needs to be discouraged. Production of fuel efficient 4-stroke engines has been initiated at a small scale. The Government should give incentives for popularizing the production of 4-stroke engines. In fact. 4-stroke technology should be made mandatory for two-wheelers of sizes 100 cc and above. Government tax policies should be re-examined to make fuel economy and not engine size, the basis for taxation, as larger engines can be both more fuel efficient and less polluting in many applications.

Given this background, scenario 2 assumes a greater level of penetration of 4-stroke technologies in the four cities in the next decade (2001-2011) as compared to the BAU scenario.

(b) Introduction of cleaner and alternate fuel: Given the high growth of diesel use in the transport sector, technological improvements to diesel engines will be insufficient to curb diesel demand. Though for diesel buses, Indian manufacturers are in the process of upgrading engine technology to obtain up to 10% better fuel economy. This can be aided by using radial tyres for trucks and improving the quality of lubricants used in the engine, gearbox and axles to provide an additional 8-10% fuel economy benefit. Particulate traps and catalysts are good retrofit options for urban use diesel vehicles such as buses.

India, with its large reserves of gas, through pilot projects in major cities are examining conversion to natural gas power engines. CNG is better suited to spark ignition engines than diesel engines which require extensive modification for use with these fuels. Given the low cost of spark ignition engines relative to diesel engines, this option has started gaining much attention in India. This option may be particularly suitable for light-heavy urban delivery trucks and buses, and their use will result in large reductions in NO_x emissions and elimination of smoke emissions.

Scenario 2 therefore assumes that with removal of subsidies in diesel oil, dependence on diesel is likely to decline in the next decade and would be substituted by CNG and battery operated vehicles (BOVs).

(c) Development of CNG including propane for transportation: Government of India in 1992 through the Ministry of Petroleum and Natural Gas selected the Gas Authority of India Limited (GAIL) as a nodal agency for implementing CNG pilot phase operation in Delhi, Mumbai and Vadodara in Gujarat State. On a pilot scale operation three mother stations, one each in Delhi, Mumbai and Vadodara were established with 5 retail outlets in Delhi, 4 in Mumbai and 2 in Vadodara to serve the retrofitted CNG vehicles. Six diesel buses of Delhi Transport Corporation (DTC) were also converted on dual fuel mode. The R & D projects in regard to application of CNG and propane in three wheelers were undertaken at Indian Institute of Petroleum (IIP), Dehradun and Automotive Research Association of India (ARAI), Pune, respectively. At the end of the pilot phase operation, the conclusion has been:

- CNG retrofitting on petrol vehicles is technically workable and commercially viable both in terms of environmental protection and cost benefits.
- The dual fuel mode operation of diesel bus was not found encouraging from the economic point of view. A dedicated CNG bus is an acceptable proposition.
- The three-wheelers conversion to CNG has been technically acceptable but initial cost of the kit including physical location and lubrication system are still to be

addressed for commercial adoption.

The following agencies are involved for implementation of CNG programme in Delhi and Mumbai: 1/ Oil marketing companies for offering the retail outlets; 2/ Kit suppliers; 3/ Conversion workshops; 4/ Vehicle manufacturers and users; 5/ Statutory authorities. For instance in Mumbai the type approving authorities are ARAI, IIP, BMC, BEST/ BSES and Regional Transport Office (RTO); 6/ Gas Supplying Company, like in Mumbai, Mahanagar Gas Limited (MGL), Gas Authority of India Limited (GAIL), Oil and Natural Gas Commission (ONGC), etc.

In view of the development of CNG taking place in Delhi and Mumbai, it is assumed that CNG based vehicles will play a greater role in these two cities in the coming decade as compared to the BAU scenario. While, in Calcutta and Bangalore no CNG based vehicles would exist in the next decade due to the lack of its infrastructure layout in the two cities.

(d) Development of BOVs: Battery operated three wheelers, cars and buses as an alternative to the conventional ones has been considered for introduction in the four cities in a gradual manner during the next decade to minimize local environmental impacts.

In view of these considerations, the new and efficient technological options which are considered for analysis in scenario 2 include: 4-stroke engines with three-way catalytic convertors for two-wheelers, propane based three-wheelers, CNG based cars/jeeps and taxis. and buses. In addition to this, battery operated three-wheelers, car and jeep and buses is also promoted in scenario 2.

Scenario 3: Strengthening of public buses, efficient technologies and cleaner fuel
This scenario integrates the result of scenario 1 and 2 and provide the overall impact on energy demand and emissions.

4.1.3. Financial analysis of alternative clean technologies

In addition to the LEAP results, an attempt has also been made to examine the financial feasibility on the basis of net present value of introducing two alternative cleaner technologies on city roads in India. These include - (1) BOVs as an alternative to the conventional 2-stroke three wheelers or autorickshaws, and (2) use of CNG as an alternative to the conventional passenger cars.

4.2. Power sector

4.2.1. Power requirement and supply potential

The first objective in the study is to estimate the demands for power in the cities for the future years in order to examine the demand-supply situation and to estimate the level of emissions which would be emitted in the cities in the base case. The requirements for power in the cities have been projected on the basis of past growth trends as well as rates projected by the planning authorities.

For the purpose of examining the trends of energy consumption and impacts of emissions from such energy use, the city area which is generally taken up for planning purposes and which is especially susceptible to changes in environmental impacts due to social and economic activity has been delineated. The requirements of power and plans for capacity addition would effectively arise in response to the requirement posed by population pressure, energy intensive lifestyles and changing levels of economic activity. Even though planning in the power sector is not done at the city level as such in India and power development plans are made for the regions as a whole, it is expected that changes in the demographic or economic profile of the city would definitely have a bearing on the demand-supply position of the city.

As a first step, the electricity requirement at the city level on a per capita basis is examined. Since total consumption of a city would be influenced both by domestic/private consumption as also industrial development processes, the per capita requirement has been restricted to non-industrial consumption. This includes domestic, commercial, public lighting and water works, railway traction and miscellaneous uses since it is expected that these categories of consumption would be dependent on population growth within the city. The trends in per capita electricity consumption are sought to be examined with respect to the socio-economic and demographic characteristics of the cities.

Based on the requirements of electricity in the cities, the generation which is met from within the city limits as against purchases from the neighbouring regions is analyzed. The existence of local generating capacity has a direct bearing on the level of fuel consumption within the city limits, and the level of resultant emissions to which the population of the city would be exposed (depending on the efficiency with which the fuel and control technologies are used).

On the basis of the specific fuel consumption for each of the plants and the generation levels, the quantum of fuels consumed by each plant in the city has been estimated. The specific fuel consumption is indicative of the efficiency of the power plants and the older plants which are more inefficient (as in case of Mulajore and New Cossipore in Calcutta) have higher specific fuel consumptions of approximately 0.9 kg/kWh as compared to the newer plants using pulverized fuel technology which have a specific fuel consumption of approximately 0.6 kg/kWh.

Specific fuel consumption x *generation = Total fuel consumption*

Next, depending on the fuel consumed, the emissions for the various pollutants (TSP, NO_x, SO_2, CO, HC) are calculated using the methodology given below. Emission factors provided by the CPCB and WHO have been used to estimate the level of emissions of various air pollutants.

Emission factor x *total fuel consumption = uncontrolled emission*

Where possible, the quality of fuels used and the technologies used by the power plants have been taken into consideration to estimate emissions emanating from these power plants from 1988/89 to 1994/95 within the city limits.

In the future, gas based power generating capacity is the most likely option from the environmental point of view. However, with the availability of large resources of coal in India, it is expected that substantial coal based power generation would continue to exist. Therefore, various clean coal technologies have been examined to analyze the pros and cons with respect to the adoption of any of these technologies.

Alternative scenarios of reduced emissions as compared to the base case have been developed. Based on the generation levels and specific fuel consumption levels in Delhi, Calcutta and Mumbai till the year 2001.02, the resultant emissions under the BAU scenario and alternative scenarios adopting cleaner technologies are computed and the emission reduction potential under each alternative case is examined.

4.2.2. Scenario construction and assumptions

Five alternative scenarios are considered to study the impact of different policy initiatives in the power sector that would reduce the total energy requirement and emissions in the three cities (excepting Bangalore) with respect to the business-as-usual or base case scenario. Bangalore does not have any major power station located within the city limits.

4.2.2.1. Business-as-usual or base case

In the business-as-usual or the base case scenario, we have assumed that the growth rates projected for power requirement in the respective regions holds for each of the power plants located within the cities. On this basis, the total power required by each of the plants in the 3 cities has been projected. Till date, the existing specific fuel consumption figures have been considered. For the future, it has been assumed that the specific fuel consumption rates do not change from the current rates and remain constant till 2002. Accordingly, the use of fuels for power generation by various technologies in the 3 cities is estimated. Based on the type of pollution control device installed in each of the plants, the pollution levels are estimated in the base case.

Even though it is generally stated that ESPs function at 99% efficiency levels, the base case assumes that the ESPs are working at 95% efficiency (which includes maintenance time etc). In case of Multi cyclones (for 2 CESC plants in Calcutta), the base case efficiency has been assumed to be 85%.

The alternative scenario would be restricted to looking at technological/fuel choices which have lower emission levels and which could replace the existing technologies.

4.2.2.2. Alternative scenarios to contain energy demand and emissions

Scenario 1: Better housekeeping and operating practices

This is a "win-win" alternative which can be adopted by power plants at negligible cost by gearing up their housekeeping measures and operating practices. Such changes have been included since 1997/98.

Scenario 2: Better control technology *(enhanced performance of ESPs and Multicyclones)*

This scenario would consider the case where any plant which does not have an ESP would have it installed and plants with control equipment working at 95% efficiency (as in the base case) are assumed to work at 99.% efficiency. Multicyclones are expected to work at 90% efficiency as compared to 85% in the base case. The improved efficiencies have been considered to be existant over the entire time period.

Scenario 3: Low NO_x combustion

Even though no policy exists for monitoring the levels of NO_x and SO_2 emissions, it is important to consider their reduction especially in light of future developments in policy and environmental control. The technology is made available from 1997/98 onwards.

Scenario 4: Sorbent injection

The sorbent injection technology is particularly important in order to control SO_2 emissions only. The technology is assumed to be available from 1997/98 onwards.

Scenario 5: Coal washing for TSP reduction

This scenario considers the option of washing coal for reducing its ash content and consequently its TSP emissions, due to increase in operating efficiency of the plant apart from reduced ash levels.

In addition to the introduction of control technologies defined in scenarios 1 to 5, advanced clean coal technologies, like, Atmospheric Fluidized Bed Combustion (AFBC), Pressurized Fluidized Bed Combustion (PFBC) and Integrated Gasification Combined Cycle (IGCC) technologies are likely to be introduced for power generation in India. Relative merits of these technologies are also discussed briefly in chapter 5.

4.3. Industrial sector

An attempt has been made to study the trends in industrial energy intensities and the associated environmental implications in the four cities under study. Very little data is available regarding the industrial units and their operational aspects in the cities under study In some cases, no inventory even exists, and whatever information available is either an approximation or very old.

The only published source of information on industries, is the Annual Survey of Industries (ASI) published by the Central Statistical Organization, Government of India. However, ASI covers only the registered factories under the Indian Factories Act, 1948.

A registered factory implies any premises where:

- ten or more workers are working or were working on any day of the preceding twelve months and where a manufacturing process is being carried on with the aid of power.
- twenty or more workers are working or were working on any day of the preceding twelve months and where a manufacturing process is being carried on (this does not include a mine subject or railway running shed).

ASI compiles industrial data in two different series. viz., one series is brought out every year consisting of monetary data for various parameters including energy consumption, inputs, outputs, value added. etc. for NIC two digit level industries state-wise and not at the city level; and the second series is a more detailed data published once in every five years which includes detailed data on actual fuel consumption, production, inputs, outputs, plant and machinery, etc. for the NIC four digit level industries which runs in to 15 volumes and is available for the years 1978/79, 1983/84, 1989/90 and 1993/94. This ASI detailed survey data for factory sector covers all the manufacturing industries represented by NIC codes 20 to 39 the description of which is given in Table 4.1.

In the absence of city level energy related information in physical units, the states in which these cities are situated (viz. Delhi in Delhi state, Calcutta in West Bengal state, Mumbai in Maharashtra, and Bangalore in Karnataka state) have been considered for compiling data required in accomplishing the task of identification of energy intensive industries.

A three step procedure is adopted using the published Annual Survey of Industries data to analyze energy demand and its composition in energy intensive industries.

Table 4.1. National Industrial Classification for manufacturing industries

NIC Code	Type of industry
20-21	Manufacturing of food products
22	Manufacture of beverages, tobacco and related products
23	Manufacture of cotton textiles
24	Manufacture of wool, silk and man-made fibre textiles
25	Manufacture of jute and other vegetable fibre textiles (except cotton and coir)
26	Manufacture of textile products (including wearing apparel)
27	Manufacture of wood and wood products; furniture and fixtures
28	Manufacture of paper and paper products and printing, publishing and allied industries
29	Manufacture of leather and products of leather, fur and substitutes of leather
30	Manufacture of basic chemicals and chemical products (except products of petroleum and coal)
31	Manufacture of rubber, plastic, petroleum and coal products; processing of nuclear fuels
32	Manufacture of non-metallic mineral products
33	Basic metal and alloys industries
34	Manufacture of metal products and parts, except machinery and equipment
35-36	Manufacture of machinery and equipment other than transport equipment (manufacture of scientific equipment, photographic/cinematographic equipment and watches and clocks is classified in Division 38)
37	Manufacture of transport equipment and parts
38	Other manufacturing industries
39	Repair of capital goods

Step 1: Identification of energy intensive industries,

Step 2. Analyze the structure of energy demand and its composition in the identified industries, and

Step 3 Estimate the emissions from the industries.

4.3.1. Identification of energy intensive industries

Energy intensity of a particular industry is termed as the ratio of the total fuel consumed in an industry to the net value added by that industry. Energy intensive industries can be studied essentially using the variables such as fuel consumption of the individual industry, fuel consumption of the overall manufacturing sector, input cost of the individual industry and value addition by the manufacturing sector.

The energy intensive industries are identified by a combined ranking method. However, for identifying energy intensive industries in manufacturing sector, it will be a very tedious exercise to use the physical data of fuel consumption. A simple and easily available source of information would be fuel cost which could be used as a substitute while studying the energy intensive industries.

For use in the combine ranking method, data on the following variables - number of factories, depreciation, fuels consumed, net value added, total input, profits, value of output - was compiled at the all India level and the four states (viz., Delhi, West Bengal, Maharashtra and Karnataka) for the manufacturing industries at two digit level as classified by NIC (i.e. 20 to 39) for the years 1983/84 and 1988/89 to 1992/93.

This data was then processed for calculating the averages of the parameters required viz., fuel cost of each industry, total input cost of each industry, total fuel cost of the manufacturing sector, total value addition by the manufacturing sector. Using these parameters, the following three variables were then calculated for all the 2-digit level (manufacturing) industries in the respective states.

$$V_1 = \frac{\text{Fuel cost of the particular industry}}{\text{Total input cost of that particular industry}}$$

$$V_2 = \frac{\text{Fuel cost of the particular industry}}{\text{Total fuel cost (of all manufacturing industries)}}$$

$$V_3 = \frac{\text{Fuel cost of the particular industry}}{\text{Total value addition by all manufacturing industries}}$$

For computing the combined ranking of industries (to determine the energy intensive industries), a two step method is used. In the first step ranks are assigned to each of the three variables as highest rank for the (a) highest value of V_1, (b) highest value of V_2, and (c) lowest value of V_3. In the second step, compute the combined ranks by adding the ranks of (a) V_1 and V_2, and (b) V_2 and V_3. Finally, the highest ranks are assigned to the lowest value of the added rank of V_1 and V_2, and V_2 and V_3.

The industries with high ranks are the energy intensive industries. Using this criteria, the energy intensive industries in all the four states have been identified in the order of hierarchy. They include industries 20-21, 23, 24, 25, 28, 30, 31, 32 and 33. State-wise list of energy intensive industries in the four states are summarized in Table 4.2.

Having identified the energy intensive industries, the next step is to understand the structure of energy demand and its composition in these industries so as to analyze the associated pollution problems from these industries. Analysing energy intensity trends will help us in understanding the structural changes in the industry over a period of time. Energy intensity can also be a means of determining various measures to restructure the industry based on the best practices followed by other similar industries. However, since city specific energy consumption data for the manufacturing industries is not available even from the ASI data, and as data is available only for Delhi which is a state by itself, a detailed analysis of energy demand and changes in energy intensities has been carried out and pollution emissions from these industries were estimated for Delhi, details of which are presented in the following section.

Table 4.2. Identified energy intensive manufacturing industries in the four states

Rank ->	Energy intensive industries (in the decreasing order of hierarchy)					
	1	2	3	4	5	6
All India	33	32	30	23	28	20-21
Delhi	20-21	30	23	33	31	32
Karnataka (Bangalore)	33	32	28	30	23	20-21
Maharashtra (Mumbai)	33	32	23	30	24	20-21
West Bengal (Calcutta)	33	32	20-21	30	25	23

4.3.2. Trends in energy intensities in industries in Delhi

The detailed ASI data for factory sector, which is published once in every five years, organized in the form of 10 tables for each industry, and is given state-wise, is available for the years 1978/79, 1983/84, 1989/90 and 1993/94. However, since the data for 1978/79 and 1983/84 was very old, data for the years 1989/90 and 1993/94 was considered for analysis.

The energy consumption data for all the identified energy intensive industries in Delhi viz., industry 20-21, 30, 23, 33, 31, 32. In addition to these six groups of industries, industries of the type 28 and 24 has also been analyzed as these two industries are important in other cities. Data is analyzed for 1989/90 and 1993/94 for the following parameters - energy use in terms of coal (tonnes), lignite (tonnes), coal gas (thousand cubic meters), liquified petroleum gas (tonnes), natural gas (thousand cubic meters), petrol (thousand litres), diesel (thousand litres), furnace oil (thousand litres), other fuel oil (thousand litres), lubricating oil (thousand litres) and electricity purchased (thousand kilowatt hours), cost data in terms of net value added, input (thousand rupees), output (thousand rupees), depreciation (thousand rupees) and gross value of plant and machinery (thousand rupees).

Energy intensities for all the industries have been calculated. While calculating energy intensities of the various industries, the energy data, which is available in physical units of the respective fuels consumed, has been converted into common units (tonnes) i.e., in terms of tonnes of oil equivalent (toe). For converting the quantities of various fuels, standard conversion factors have been used (Table 4.3.).

Table 4.3. Conversion factors for fuels (to oil equivalent)

Fuel	Unit	Conversion factor
Coal	tonnes	0.49
Lignite	tonnes	0.2265
Coal gas	'000 cum	0.4118
LPG	tonnes	1.1414
Natural gas	'000 cum	0.8569
Petrol	'000 litres	1.0294
Diesel	'000 litres	1.0098
Furnace oil	'000 litres	0.9337
Other fuel oil	'000 litres	0.9412
Lubrication oil	'000 litres	0.8977
Electricity	GWh	0 843

Note The conversion factors for coal, lignite and electricity have been based on the published information from TERI Energy Data Directory Yearbook (TEDDY), 1995/96 published by TERI, New Delhi, and for LPG, petrol, diesel, furnace oil, other furnace oil and lubrication oil are based on the information from Petroleum and Natural Gas statistics published annually by the Ministry of Petroleum and Natural Gas, Govt. of India.

Source Compiled from

a) TERI, Tata Energy Data Directory Year Book, 1996/97, New Delhi: Tata Energy Research Institute (TERI), 258 pp

b) Govt. of India, Indian Petroleum and Natural Gas Statistics, 1993/94, New Delhi: Ministry of Petroleum, 217 pp.

For analysing the energy consumption data, the various fuels have been grouped into four categories namely, coal (includes coal, lignite and coal gas), natural gas (includes LPG also), oil (includes petrol, diesel, furnace oil, other fuel oil and lubricating oil) and electricity purchased. All cost figures relating to these parameters has been brought to constant prices with the base year as 1981/82 using the wholesale price index for the respective years (*Government of India, 1996/97*).

A detailed exercise has been carried out to study the changes in the energy intensities, and related parameters such as changes in net value added, the ratio of net value added to input, gross value of plant and machinery, energy mix and fuel shares to understand the impacts on the industry and the environment. An analysis of the changes in energy intensity and the possible causes has been made to draw upon conclusions regarding the trends in the industry. Also, the likely environmental implications has been studied in terms of emissions from the energy intensive industries.

4.3.3. Estimation of emissions from the energy intensive industries

The emissions from energy intensive industries are due to combustion of various fuels in these industries. Besides use of electricity, the major fuels consumed in these industries include coal, natural gas, fuel oil and diesel. The major pollutants from the industries include TSP, SO_2, NO_x, CO and HC. Here, an attempt has been made to estimate the emissions from industries, essentially to see the impact of energy consumption. Uncontrolled emissions from industries have been estimated by multiplying emission factors and fuel consumption.

The emission factors used for industrial sources, are mainly derived from the emission factors suggested by the World Health Organization (WHO) and United States Environment Protection Agency (USEPA) (AP42). Also, the URBAIR Greater Mumbai Report, a recent study conducted by the World Bank in India, has been consulted for the emission factors used in the Indian context (which also consulted the USEPA and WHO factors). The emission factors used are given in Table 4.4.

The fuel consumption data for coal, natural gas and oil (including fuel oil, furnace oil and diesel) for all the energy intensive industries in Delhi was compiled. While considering the oil consumption data, since the difference in the calorific value for fuel oil and diesel is negligible (less than 6%), and the fuel oil is the major fuel consumed, these fuels have been considered together in oil equivalent value and the emission factors for fuel oil have been used for estimating the emissions from them. The uncontrolled total emissions of TSP, SO_2, NO_x, CO and HC are estimated as no generalized information on controls could be used. The changes in pollution levels and the associated environmental implications form the industry have been analysed and discussed in the light of the growth patterns and trends in energy intensities of the industries.

Table 4.4 Emission factors

Pollutant	Coal (g/kg)	Natural Gas (g/m^3)	Fuel Oil (g/kg)
TSP	6.5 A	0.048	1.32 S + 0.4
SO_2	19 S	15.6 S	20 S
CO	1	0.272	0.64
HC	0.5	0.048	0.13
NO	7.5	2.24	7

Note A is the ash content and S is the sulphur content in the respective fuels under consideration.

Source Compiled from

(a) USEPA, 1986. Taken from the URBAIR report, 1996

(b) WHO, 1993 Assessment of sources of air, water and land pollution, Part One: Rapid inventory techniques in environmental pollution by Alexander P. Economopoulos, World Health Organization, Geneva.

CHAPTER 5

Results and Analysis

5.1. Transport sector

5.1.1. BAU scenario

This section deals with the BAU scenario which assumes that the present trends of growth in registration of vehicles in the four cities will continue, while the present fuel efficiency norms, occupancy levels and vehicle utilization pattern for different modes will remain unchanged in the future period.

5.1.1.1. Growth trends of motor vehicle registrations

Among all the towns and cities (total 3609 during 1990/91) in India, Delhi has recorded the largest motorized vehicle population of over 2.32 million in 1994/95 even though it ranks third in the list of megacities of the country after Mumbai with 0.67 million vehicles and Calcutta 0.56 million vehicles. It is interesting to note that the vehicle population of Mumbai, Calcutta and Bangalore taken together accounts for 2.03 million which is even less than vehicle population of Delhi alone during in 1994/95. Perhaps this is due to the fact that Mumbai and Calcutta have suburban rail services unlike Delhi.

Annexure 5.1 in volume II gives the growth in total registration of motorized vehicles and its breakup by modes in the four cities from 1984/85 to 1994/95. The same data is plotted in Figure 5.1. During this ten year period the average annual growth rate of total vehicles registered has gone up by 11.2% for Delhi, 7% for Calcutta, 4.5% for Mumbai and 11.1% for Bangalore (Annexure 5.2). However, the corresponding annual growth rate in the four cities declined to 7.8%, 4.2%, 1.5% and 8.4% respectively between 1990/91 and 1994/95 (Annexure 5.2). Annexure 5.2 also gives the average annual growth rate of different modes of transport in the four cities. One noticeable feature about the growth is the large number of registered two wheelers and explosion in their growth rates in the four cities. Two wheelers in Delhi, Calcutta, Mumbai and Bangalore have experienced an average annual growth rate of 10.8%, 11.1%, 7.4% and 12.1% respectively between 1984/85 and 1994/95. This huge growth in scooter and motorcycle ownership has been due to relaxation of government industrial policies and import levies since the early 1980's. But in the recent past (i.e., from 1990/91 to 1994/95) these annual growth rates have declined to 7.3%, 6.1%, 3.7%, 7.7% respectively, due to an economic downturn in some sectors and price increases affecting motor cycles and scooters. Rate of growth of car and jeep has also been high in the four cities. Between 1984/85 and 1994/95, the average annual growth rate of car and jeep together account for 13.8% in Delhi, 4.4% in Calcutta, 2.7% in Mumbai, and 7.9% in Bangalore. But these rates have declined between 1990/91

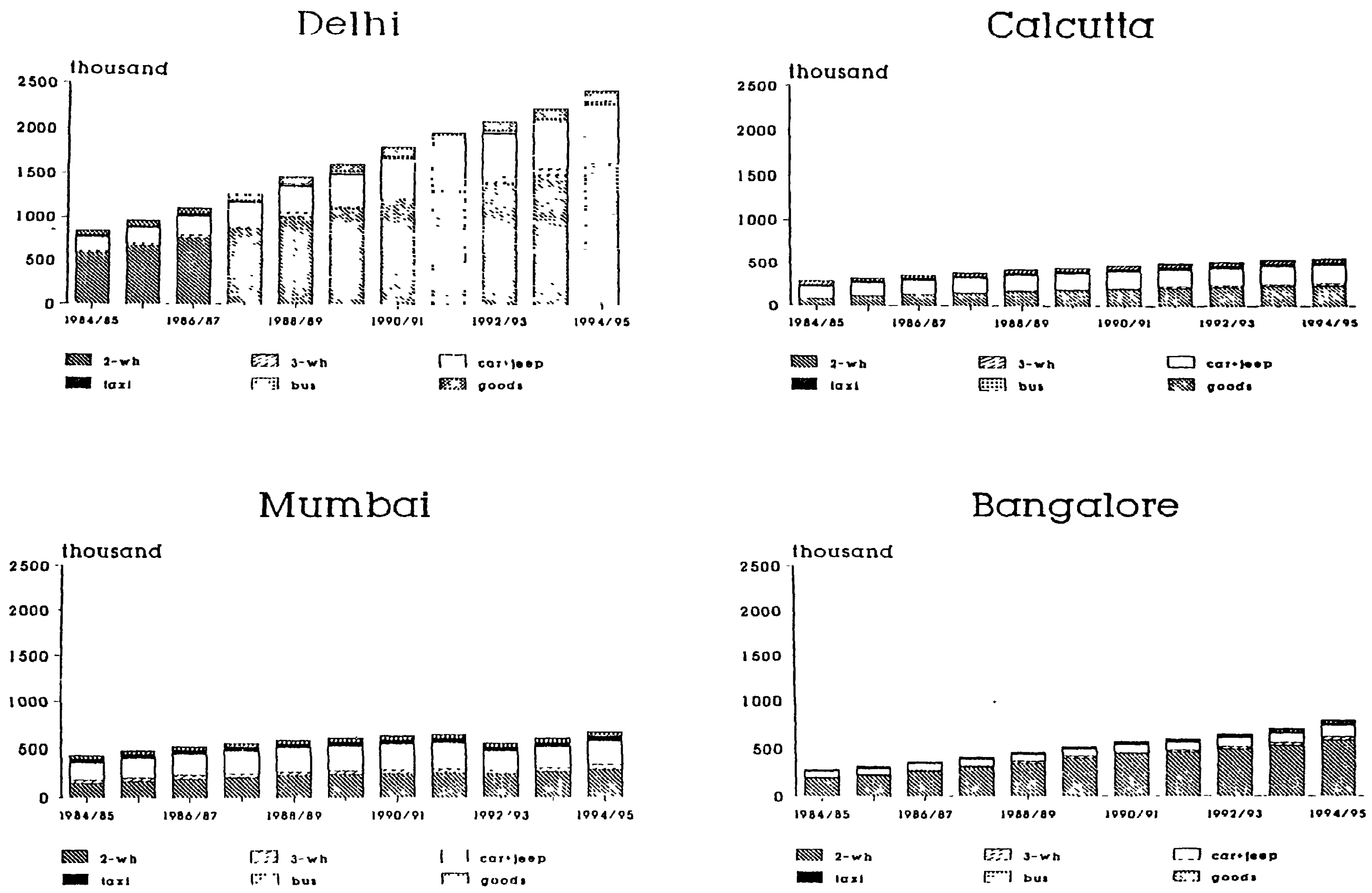

Fig.5.1 Trends in vehicle registration

and 1994/95. It is interesting to note that three wheeler autorickshaw is also growing very fast in the four cities, particularly in Calcutta, where it was introduced in early 1980s. It can be noticed from Annexure 5.1 that in one year period (i.e. between 1984/85 and 1985/86) three wheeler registration in Calcutta has gone up 23 times, however between 1985/86 and 1994/95 it has gone up by 6 times.

5.1.1.2. Changes in vehicle registrations composition

The vehicle composition are quite different in the four cities (Annexure 5.3). Among the personalized vehicles, there is a growing dependence on use of scooters and motorcycles since 1984/85 in each of the four cities. In Delhi and Bangalore, the share of two wheelers (i.e., scooters and motorcycles) is 67% and 75% respectively in 1994/95, but in Calcutta and Mumbai its share is only 44% and 42%. The share of car and jeep has declined in Calcutta, Mumbai and Bangalore between 1984/85 and 1994/95. The share of car and jeep together in Calcutta has gone down from 47% in 1984/85 to 37% in 1994/95, 42% to 35% in Mumbai, and 19% to 14% in Bangalore, while during the same period, Delhi has experienced an increasing share of car and jeep from 19% to 24%. The implications of rapid rise in two wheelers and car/jeep together with their large share in each of the four cities are grave for the spread of traffic congestion and increasing demand for their parking facilities.

Among the intermediate public transport, the share of three wheeler autorickshaw in Delhi has declined marginally from 3.6% to 3.1% during the ten year period. In Calcutta, share of three wheelers have increased from 0.06% to 4.39%, while in Mumbai and Bangalore, its share has declined till early 1990's and has again increased. The share of taxi as another mode of intermediate public transport, has shown a declining trend from 1% in 1984/85 to 0.5% in 1994/95 in Delhi, 0.7% to 0.5% in Bangalore. While in Calcutta its share has remained around 3.5% and in Mumbai around 6% during the ten year period.

As far as the public transport bus is concerned, its share in Delhi and Bangalore has marginally declined from 1984/85 to 1994/95. In Delhi the share has gone down from 1.6% to 1.1% and in Bangalore from 2.2% to 1.3%. While in the other two cities, share of bus has marginally increased. Its share in Calcutta has gone up from about 2% to 2.4%, while in Mumbai it has gone up from 1.4% to 1.8%.

In all the four cities, the share of goods vehicles registered have declined since 1984/85. Its share in Delhi has decreased steadily from 6% in 1984/85 to 5.1% in 1994/95. In Calcutta the share of goods vehicles registered has decreased from 17% in 1984/85 to 8.3% in 1994/95, while in Mumbai the share has marginally declined from 7.7% to 6.2%, and in Bangalore from 5.6% to 4.8%.

5.1.1.3 Projection of passenger vehicles with attrition

Annexure 5.4 gives the estimated regression coefficients of the time trend equation (4.1) for different motorized modes in three cities - Delhi, Calcutta and Bangalore. These equations are used for extrapolating the future growth of different vehicles using the time series data on registration of motor vehicles from 1984/85 to 1994/95. However, for Mumbai, extrapolation of vehicles are based on CAGR in two year period - between 1992/93 and 1994/95. This is because, since 1992/93, the registration of vehicle office in Mumbai has been split into two. One in Mumbai (i.e., Greater Mumbai) and another in the outer cordon of Mumbai (i.e., the Greater Mumbai limits). As a result of which some of the registered vehicles in Mumbai prior to 1992/93 were shifted to the outer cordon after 1992/93. This has resulted in a decline of total vehicles registered in Mumbai in 1992/93 (Annexure 5.1). The estimated CAGR for different modes of vehicles in Mumbai are given in Annexure 5.4.

The estimated vehicles for the reference years 1995/96, 2000/01, 2005/06 and 2010/11 are then adjusted with appropriate attrition factors. It is assumed that the attrition factor of a two-wheeler is 15 years, three-wheeler 20 years, car/jeep and taxi 25 years, while that of a bus to be 10 years. For instance, this would mean, the total number of two wheelers on road in 2000/01 would be equal to the difference between registered two-wheelers in 2000/01 obtained from the time trend equation (4.1) and the registration of two wheelers in 1985 86. The registration of vehicles adjusted with appropriate attrition provide its total size in a given year.

Figure 5.2 presents the number of registered passenger vehicles in 1990/91 and extrapolation of vehicles for 1995/96. 2000 01. 2005/06 and 2010/11 with an appropriate attrition factor. The number of vehicles in Delhi is expected to go up by almost 40% in a fifteen year period from 1.9 million in 1995 96 to 2.8 million in 2010/11. While the growth in fleet stock in Calcutta would be 19% (0.44 to 0.53 million), Mumbai 77% (0.42 to 0.73 million) and Bangalore 49% (0.65 to 0.97 million) during the same period.

In terms of vehicular composition. in Delhi, Calcutta and Bangalore, the share of scooters and motorcycles would continue to dominate but is expected to decline in future as given in Table 5.1.

For Mumbai, it is assumed that the composition of different modes would remain constant between 1990/91 and 2010/11. The share of car and jeep in Delhi is likely to increase from 27% to 38%, while in Calcutta and Bangalore the share of car would decline from 1990/91 to 2010/11. The share of bus would increase marginally and would be little over 1% in Delhi. In Calcutta, the share of bus which is currently only 0.6% is expected to decline further 0.5% in 2011/12. While in Bangalore with present share of bus being 0.7% is expected to rise upto 0.9% by 2010/11. However in Mumbai bus share is assumed to

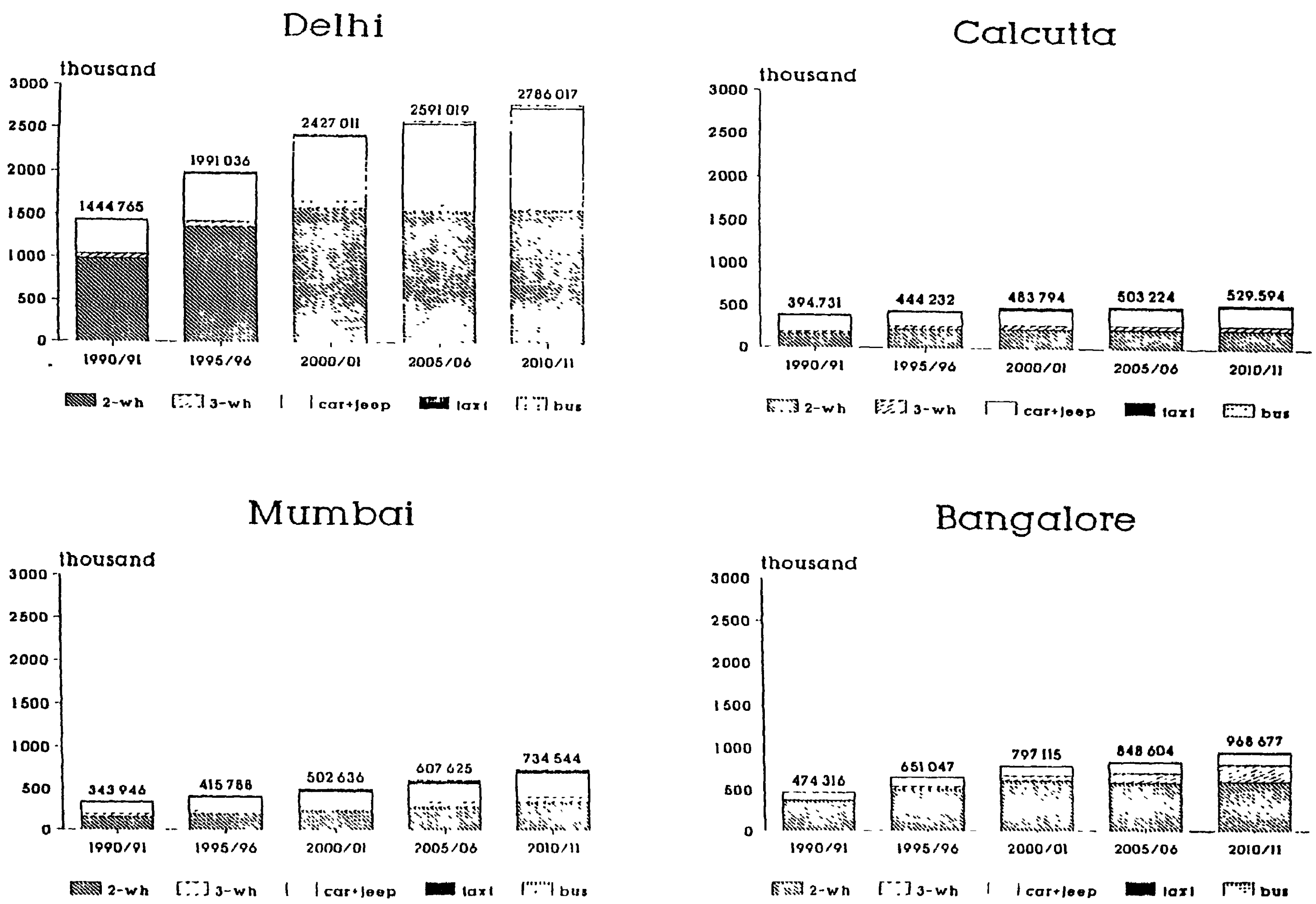

Fig.5.2 Growth of registered vehicles with attrition factors

Table 5.1. Vehicular composition with attrition factor - past, present and future

City	Year	Composition (%)					Total passenger vehicles	Composition %		Total freight vehicles
		2-wh	3-wh	car+jeep	taxi	bus		HCV	LCV	
Delhi	1990/91	68.01	3.61	26.99	0.70	0.68	1444765	46.96	53.04	79214
	1995/96	68.13	3.45	27.32	0.43	0.67	1991036	44.90	55.10	104684
	2000/01	65.12	3.65	29.99	0.44	0.81	2427011	42.00	58.00	102976
	2005/06	59.70	3.57	35.19	0.51	1.03	2591019	38.99	61.01	87711
	2010/11	56.21	3.46	38.47	0.51	1.35	2786016	35.00	65.00	72717
Calcutta	1990/91	42.25	5.14	47.20	4.87	0.54	394731	49.94	50.06	14986
	1995/96	50.50	6.85	38.10	3.95	0.60	444232	56.29	43.71	16791
	2000/01	47.39	8.94	38.60	4.51	0.55	483794	55.00	45.00	19589
	2005/06	45.01	9.13	40.59	4.74	0.53	503224	45.00	55.00	20069
	2010/11	43.25	9.19	42.18	4.88	0.51	529594	40.00	60.00	19375
Mumbai	1990/91	45.26	10.53	36.84	5.26	2.11	343946	48.92	51.08	18102
	1995/96	45.26	10.53	36.84	5.26	2.11	415788	41.56	58.44	21883
	2000/01	45.26	10.53	36.84	5.26	2.11	502636	40.00	60.00	26455
	2005/06	45.26	10.53	36.84	5.26	2.11	607625	38.00	62.00	31981
	2010/11	45.26	10.53	36.84	5.26	2.11	734544	36.00	64.00	38661
Bangalore	1990/91	78.76	2.42	17.84	0.51	0.46	474316	49.68	50.32	12981
	1995/96	79.40	4.51	15.02	0.37	0.69	651047	35.61	64.39	21446
	2000/01	77.16	7.42	14.26	0.46	0.71	797115	34.00	66.00	10873
	2005/06	69.70	13.63	15.26	0.64	0.77	848604	32.00	68.00	7624
	2010/11	62.73	21.84	13.80	0.76	0.88	968677	30.00	70.00	5000
Attrition value (years)		15	20	25	25	10	-	-	-	-

remain constant around 2%. The share of autorickshaw is expected to increase at an alarming rate from 4.5% in 1995/96 to 21.8% in 2010/11 in Bangalore and that of taxi share would increase marginally. In Delhi, autorickshaw and taxi share would remain around 3.5% and 0.5% respectively. The share of autorickshaw in Calcutta would increase from 6.9% in 1995/96 to 8.9% in 2000/01 and then would increase marginally to around 9.1% in 2010/11. Similar trend is also observed in the case of taxi in Calcutta. Its share would increase from 3.9% in 1995/96 to 4.5% in 2000/01 and then to 4.9% in 2010/11. In Mumbai, it is assumed that the share of autorickshaw and taxi would remain at 10.5% and 5.3% respectively till 2010/11. As far as goods vehicles are concerned, for which no attrition factor is assumed, the share of heavy commercial vehicle (HCV) on city roads would decline while that of the light commercial vehicle (LCV) would increase. In Delhi, share of HCV which was 47% in 1990/91 is expected to decline to 35% in 2010/11. In Calcutta, HCV share would drop from 50% to 40%, in Mumbai from 49% to 36% and in Bangalore from 50% in 1990/91 to 30% in 2010/11.

5.1.1.4. Ownership of private vehicles

Number of private vehicles (adjusted with attrition factor) per thousand people in Delhi would increase from 146 in 1990/91 to 191 in 2000/01 and then would decline to 183 in the next census decade (Table 5.2). Similar trend is observed in Bangalore also - from 112 to 128 in this decade and then to 97 at the end of the next decade.

Table 5.2. Number of vehicles (with attrition) per thousand persons

City	Modes	1990/91	1995/96	2000/01	2005/06	2010/11
Delhi	Scooter/Motor bike	104	127	131	117	109
	Car/Jeep	41	51	60	69	74
	Total private	146	178	191	186	183
	Autorickshaw	6	6	7	7	7
	Taxi	1	1	1	1	1
	Total IPT	7	7	8	8	8
Calcutta	Scooter/Motor bike	14	17	16	15	14
	Car/Jeep	16	13	13	14	14
	Total private	30	31	30	29	28
	Autorickshaw	2	2	3	3	3
	Taxi	2	1	2	2	2
	Total IPT	3	4	5	5	5
Mumbai	Scooter/Motor bike	16	17	19	21	24
	Car/Jeep	13	14	16	17	19
	Total private	28	31	35	39	43
	Autorickshaw	4	4	4	5	6
	Taxi	2	2	2	2	3
	Total IPT	5	6	7	7	8
Bangalore	Scooter/Motor bike	91	107	108	89	79
	Car/Jeep	21	20	20	20	17
	Total private	112	127	128	109	97
	Autorickshaw	3	6	10	17	28
	Taxi	1	0	1	1	1
	Total IPT	3	7	11	18	29

In Calcutta, ownership of private vehicles would remain around 30 in this decade but would decline marginally to 28 in the next decade. While in Mumbai, though ownership of private vehicles are relatively lower than the other cities but would go up steadily by over 1.5 times - from 28 vehicles per thousand people in 1991 to 43 in 2011. Table 5.2 also gives the degree of dependence on autorickshaws and taxis as intermediate public transport (IPT). Dependence on IPT maximum in Bangalore and would grow very fast. In the other cities role of IPTs would marginally increase and would be in the range of 5-8 vehicles per thousand people in 2011.

5.1.1.5. Travel demand and modal split

The passenger and freight travel demand is estimated using Eq.(4.2) in the four cities for the period 1990/91 to 2010/11 in five yearly interval. Secondary data on average occupancy of passenger vehicles, average load carried by goods vehicles and utilization of different vehicles, given in Table 5.3, are used in Eq.(4.2) for estimating the travel demand.

Table 5.3. Average seating capacity, load carried and daily utilization of vehicles

City	Average occupancy (persons/vehicle)					Average load carried (tonne/vehicle)	
	Scooter/M-cycle	Auto	Car/Jeep	Taxi	Bus	LCV	HCV
Delhi	1.5	1.76	2.68	1.57	37.28	0.7	5.28
	(13.5)*	(120)	(27)	(85)	(186)	(25)	(25)
Calcutta	1.5	1.76	2.59	1.57	33.76	0.7	5.28
	(13.5)	(100)	(27)	(85)	(126)	(16)	(16)
Mumbai	1.5	1.76	1.57	1.57	38 62	0.7	5.28
	(13.5)	(100)	(27)	(85)	(245)	(20)	(20)
Bangalore	1.5	1.76	2.67	1.57	39.46	0.7	5.28
	(13.5)	(100)	(27)	(85)	(262)	(16)	(16)

Figure in parentheses are average daily vehicle utilization expressed in km/l.

Source For bus - Government of India, 1993 & 1996, for all other modes - Engineering Consultants Private Ltd., 1987

Distribution of passenger travel demand by modes are further broken down into different technologies. This is done by analyzing the composition of annual sales data of different types of technologies for a given mode in the respective states of the four cities during the fourteen year period from 1981 to 1994 (Annexure 5 5). Such detailed disaggregation of passenger travel demand by technologies during 1990/91 to 2010/11 capture the penetration of different technologies in meeting the growing personal mobility in the four cities For instance, it can be noticed from Annexure 5.5 that since early 1990s the share of two stroke technologies are gradually declining and replaced with four stroke technologies in the case of motor bikes in each of the four respective states. Similarly, among the car/jeep sold in the four states, the share of Maruti car, post 1984 model technology, has increased substantially, while that of Ambassador and Premier Padmini car which are pre 1984 technology have declined. The Catalytic Convertor based unleaded gasoline cars have been introduced since 1st April 1995 in Delhi, Calcutta and Mumbai to check lead emissions from gasoline. The share of diesel based cars/taxis sold in the four states have also been estimated.

Table 5.4. gives the estimated travel demand in the four cities both for personal and goods mobility. The same table also gives the distribution of passenger and freight travel demand by various modes, which is termed as modal split.

Passenger travel demand.

Volume of total passenger travel demand in Delhi is expected to grow over 3 times from 47 billion passenger kilometre (bpkm) in 1990/91 to 143 bpkm in 2010/11 (Figure 5.3). The corresponding jump in the other three cities are - Calcutta 1.3 times (from 12 to 16 bpkm), Mumbai 2.1 times (from 31 to 67 bpkm) and Bangalore 3.9 times (from 14 to 54 bpkm) respectively. While on a per capita basis, over a 20 year period (i.e., from 1990/91 to 2010/11), average annual growth rate in travel demand daily would be around 3.5% in Delhi (from 13.7 to 27.2 km/day), 2.1% in Mumbai (from 8.7 km to 13.2 km/day) and 3.6% in Bangalore (from 9.5 km to 19.3 km/day). However in Calcutta, per capita travel demand would remain around 2.8 km/day between 1990/91 and 2010/11.

In spite of a very large fleet size of private vehicles (i.e., scooters, motor cycles, cars and jeeps) in each city, currently bus caters to a very high volume of travel demand. As given in Table 5.8, buses in Delhi currently meet about 53% of the total passenger travel demand and would increase steadily to 66% by 2010/11. While in Calcutta and Bangalore, the travel demand catered by bus is expected to decline between 1995/96 and 2010/11. In Calcutta the decline would be from 32% in 1995/96 to 26% in 2010/11. In Bangalore from 67% to 59% during the same period. In Mumbai bus share in meeting the travel demand would remain around 80% in the coming years.

Travel demand share to be catered by the personalized or private vehicles are expected to decline marginally between 1995/96 and 2010/11 in Delhi, Calcutta and Bangalore, while in Mumbai it would remain at the same level (Table 5.4). However, dependence on cleaner technologies like, four stroke engines and cars with catalytic convertors would increase. Shift from gasoline engine to diesel engine cars, jeeps and taxis is expected in the near future due to the double price differential between retail price of gasoline (about Rs 23 per litre) and diesel (about Rs 10 per litre).

Among the IPT modes, the role of three wheeler autorickshaw in meeting passenger travel demand in Bangalore would increase by about 3.5 times in 2010/11 from its current share of 7% and in Calcutta its rise would be about 1.3 times from its present share of 15%. However, in Delhi share of autorickshaw would decline from 8% in 1995/96 to 5% in 2010/11. In Mumbai autorickshaws would meet a little over 7% of the total travel demand in the next decade. Taxis are expected to meet between 1 and 7% of the travel demand in the four cities in near future.

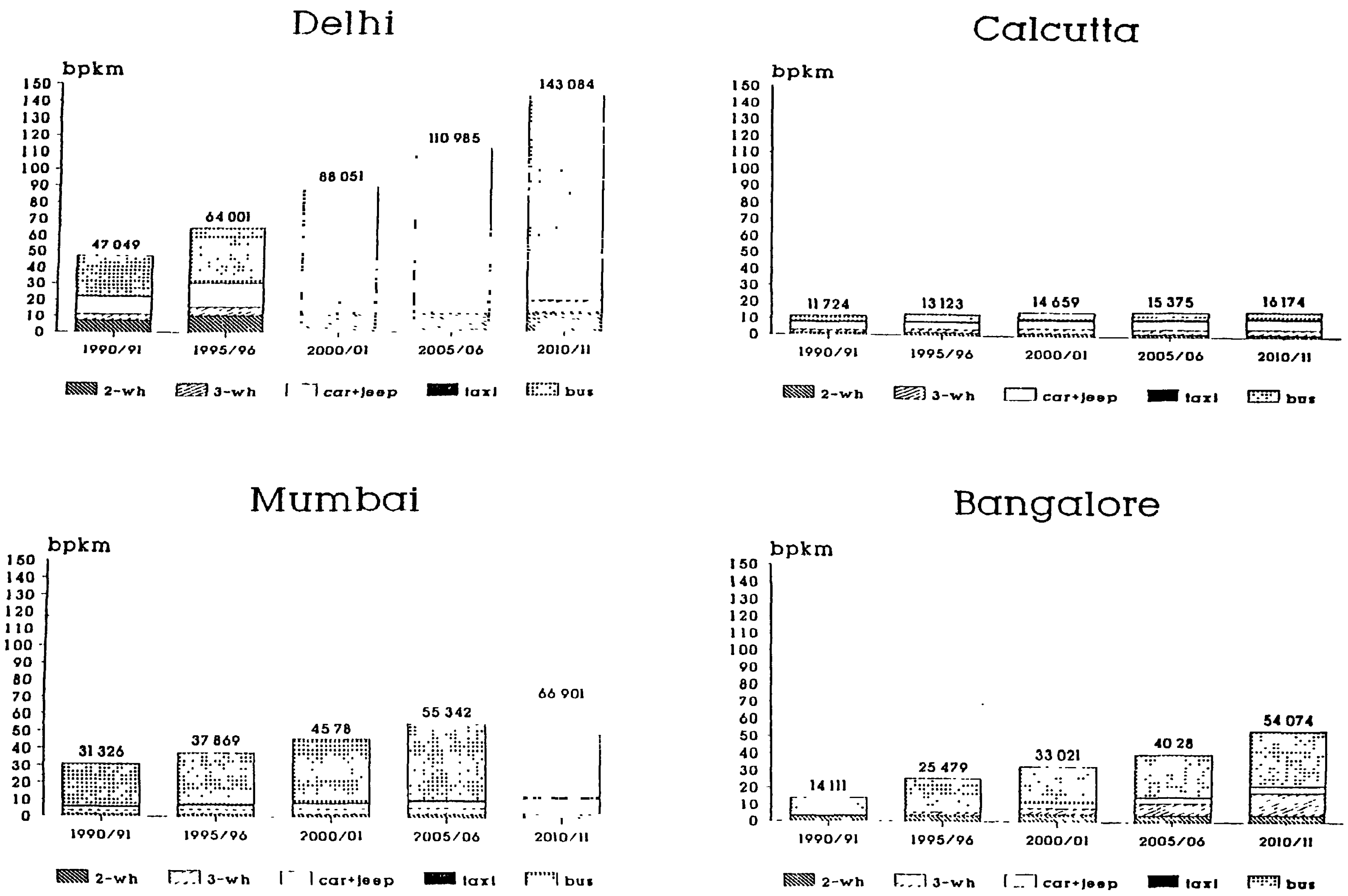

Fig.5.3 Growth in passenger travel demand and modal split

Table 5.4. Travel demand and its distribution by different modes and their technologies

City	Year	Distribution of travel demand by different types of technology (%)										Total passenger travel demand (10^9 pkm)	Per Capita travel demand (km/day)	Distribution of freight travel (%)		Total freight travel demand (10^9 tkm)
		Scooter/M-cycle		Auto	Car/Jeep				Taxi		Bus			Goods vehicles		
		2-str	4-str		pre-1984	post-1984	catalytic converter	diesel	petrol	diesel				lcv	hcv	
Delhi	1990/91	14.85	0.59	8.55	4.50	15.88	0.00	1.68	0.63	0.42	52.90	47.05	13.67	86.97	13.03	2.06
	1995/96	14.88	0.78	8.27	3.39	16.96	0.45	1.81	0.20	0.46	52.80	64.00	16.44	86.01	13.99	2.63
	2000/01	12.34	0.93	7.75	1.76	13.20	3.74	3.30	0.12	0.47	56.40	88.05	20.00	84.53	15.47	2.47
	2005/06	9.37	0.93	6.42	0.44	10.27	6.56	4.59	0.06	0.52	60.83	110.98	23.07	82.83	17.17	1.99
	2010/11	7.20	0.89	5.20	0.20	6.98	7.97	4.78	0.02	0.46	66.30	143.08	27.21	80.24	19.76	1.53
Calcutta	1990/91	9.91	0.61	11.11	16.42	12.89	0.00	12.97	4.80	3.20	28.10	11.72	2.71	88.27	11.73	0.26
	1995/96	11.62	1.01	14.89	10.98	13.04	0.69	9.61	1.96	4.56	31.65	13.12	2.79	90.67	9.33	0.32
	2000/01	10.52	1.04	18.96	8.14	8.47	5.76	11.53	1.45	5.80	28.33	14.66	2.87	90.21	9.79	0.37
	2005/06	9.69	1.20	19.20	6.01	7.07	9.54	12.73	0.75	6.79	27.01	15.38	2.82	86.06	13.94	0.32
	2010/11	9.21	1.26	19.33	4.41	5.88	12.86	13.60	0.39	7.39	25.68	16.17	2.77	83.41	16.59	0.29
Mumbai	1990/91	3.43	0.24	7.42	2.86	2.05	0.00	1.36	1.69	1.13	79.83	31.33	8.66	87.84	12.16	0.39
	1995/96	3.16	0.51	7.42	1.88	2.50	0.13	1.75	0.84	1.97	79.83	37.87	9.56	84.29	15.71	0.42
	2000/01	3.09	0.59	7.42	1.50	1.94	0.94	1.88	0.56	2.25	79.83	45.78	10.58	83.41	16.59	0.49
	2005/06	3.01	0.66	7.42	1.25	1.25	1.56	2.19	0.28	2.53	79.83	55.34	11.81	82.22	17.78	0.57
	2010/11	2.94	0.73	7.42	0.75	1.13	2.00	2.38	0.14	2.67	79.83	66.90	13.17	80.93	19.07	0.66
Bangalore	1990/91	18.32	1.25	5.23	5.34	6.66	0.00	3.96	0.50	0.33	58.40	14.11	9.45	88.16	11.84	0.23
	1995/96	12.60	2.40	7.41	2.04	5.21	0.00	2.96	0.14	0.32	66.92	25.48	14.44	80.66	19.34	0.29
	2000/01	10.60	3.17	11.50	1.47	4.76	0.00	2.93	0.11	0.43	65.04	33.02	15.84	79.53	20.47	0.14
	2005/06	7.38	3.47	18.45	1.20	4.28	0.00	3.08	0.07	0.59	61.49	40.28	16.66	78.02	21.98	0.10
	2010/11	5.15	3.16	25.13	0.72	3.22	0.00	2.63	0.03	0.63	59.33	54.07	19.29	76.37	23.63	0.06

Freight travel demand.

Freight travel demand within the city limits are also given in Table 5.4. In Mumbai, freight travel demand would increase steadily from 0.39 to 0.66 btkm between 1990/91 to 2010/11. While in Calcutta till 2000/01 freight travel demand would increase and then decline from 0.37 btkm in 2000/01 to 0.29 btkm in 2010/11. In Delhi and Bangalore, freight movement demand would decline consistently from its current level of 2.63 btkm and 0.29 btkm in 1995/96 to 1.53 btkm and 0.06 btkm in 2010/11 respectively. Currently, between 80 and 90% of the freight traffic in the four cities are catered by the LCVs but by 2010/11 their share would drop and would remain between 76-83%.

5.1.1.6. Energy demand

Energy demand module in the LEAP according to Eq. (4.3) is used to estimate annual energy consumed in the form of gasoline and diesel for passenger and freight transportation in the four cities are estimated for 1990/91 and 1995/96, and extrapolated for 2000/01, 2005/06 and 2010/11 respectively. Table 5.5 gives the average fuel efficiency norms for different modes of technologies used in Eq.(4.3).

Table 5.5 Average fuel efficiency (km/l)

Fuel	Technology	Scooter/M-cycle	Auto	Car/Jeep/Taxi	Bus	LCV	HCV
Gasoline	2-stroke	44.44	20.41				
	4-stroke	65					
	Pre-1984			9.43			
	Post-1984			14.18			
Unleaded gasoline	Catalytic convertor			14.8			
Diesel				8.86	3.3	5.55	10

Source IIP 1994

Annexure 5.6 gives the details of LEAP results for the BAU scenario. Estimates of aggregate as well as disaggregate energy demand either by fuel type or by different modes of transport further broken down into technologies are presented for the five reference years considered in this study.

Figure 5.4 summarizes the aggregate energy demand for passenger and freight transportation in the four cities. Energy required for passenger movement is substantially higher (over 95%) than freight movement in each of the four cities. Nearly 2.5 times increase in transport energy demand is expected in the city of Delhi between 1990/91 and 2010/11 (from 0.69 million tonnes of oil equivalent (mtoe) to 1.69 mtoe). In other three cities total energy required during the same 20 year period would be around that of Delhi

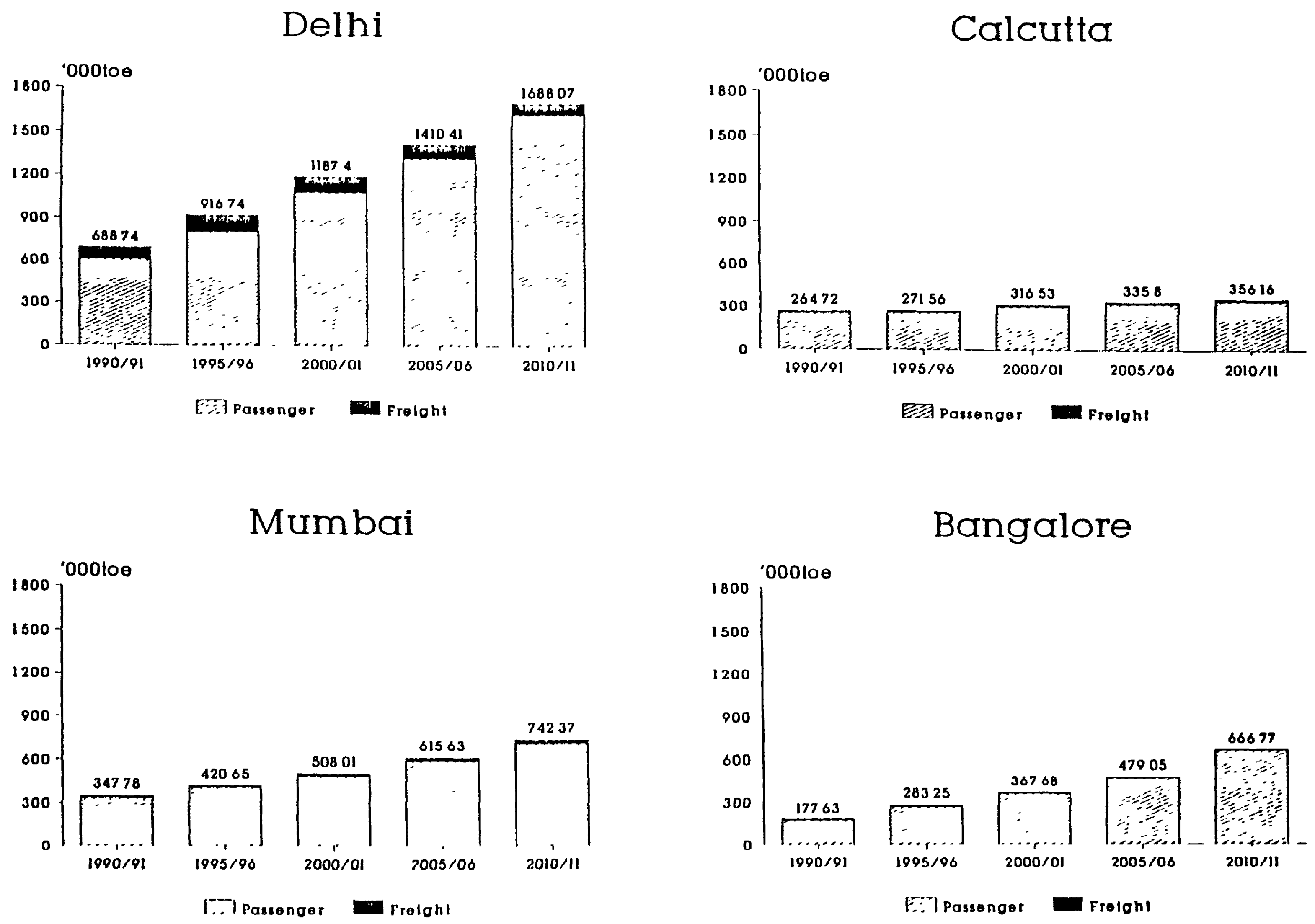

Fig. 5.4 Transport energy requirement under BAU scenario

alone. In Calcutta, the increase would be from 0.27 mtoe in 1990/91 to 0.36 mtoe in 2010/11, in Mumbai from 0.35 to 0.74 mtoe and in Bangalore from 0.18 to 0.67 mtoe.

Personal mobility.

Current annual gasoline consumption in Delhi, Calcutta, Mumbai and Bangalore are estimated to be 0.52, 0.15, 0.13 and 0.13 mtoe respectively. While the quantum of gasoline sales in these four cities are 0.48, 0.15, 0.23 and 0.12 mtoe respectively. Such deviations in estimated and actual gasoline consumption could be due to the use of normative values of fuel efficiency, occupancy and vehicle utilization levels, each of which would vary under different urban driving conditions. The other possible reason could be the vehicles going outside Delhi in most of the cases are expected to meet their fuel requirement from the neighbouring regions. Over the next 15 year period (from 1995/96 to 2010/11), annual gasoline demand is estimated to grow at 2.1% per annum (from 0.52 to 0.72 mtoe) in Delhi, 0.7% (from 0.15 to 0.17 mtoe) in Calcutta, 2.5% (from 0.13 to 0.19 mtoe) in Mumbai and 7.4% (from 0.13 to 0.38 mtoe) in Bangalore respectively.

Similarly, estimated current diesel consumption annually in the four cities are 0.28, 0.11, 0.27 and 0.14 mtoe in Delhi, Calcutta, Mumbai and Bangalore respectively. These figures corresponds to 77%, 58%, 108% and 88% respectively of the total diesel sold in the four cities during 1995/96. Except in Bangalore, annual rate of growth of diesel demand in the next 15 years (from 1995/96 to 2010/11) would be higher than the gasoline for personal mobility in the other three cities. During this period, diesel demand in Delhi would grow at 8.01% per annum (from 0.28 to 0.89 mtoe), in Calcutta 2.94% (from 0.11 to 0.17 mtoe), in Mumbai 4.21% (from 0.27 to 0.52 mtoe) and in Bangalore 4.73% (from 0.14 to 0.28 mtoe) respectively.

Table 5.6 gives annual per capita gasoline and diesel demand for personal mobility in the four cities between 1990/91 and 2010/11. Annual per capita total energy demand for personal transportation is highest in Delhi followed by Bangalore then in Mumbai and least being in Calcutta. Such a trend in transportation energy demand is expected due to non availability of rail based transportation system in Delhi and Bangalore unlike the MRTS in Calcutta and suburban rail system in Mumbai. Also, in coming future dependence on gasoline in each of the four cities would decline while that of diesel would increase as price of diesel is less than half than that of gasoline in the country.

Annual per capita total energy demand in Delhi is expected to grow from 75 kgoe in 1995/96 to 112 kgoe in 2010/11. In Mumbai the corresponding growth would be from 37 to 51 kgoe while in Bangalore from 63 to 86 kgoe respectively. In Calcutta, however, annual per capita energy demand would remain around 21 kgoe in the next fifteen year period.

Table 5.6. Annual per capita fuel requirement in passenger vehicles (kgoe/person)

Fuel	City	1990/91	1995/96	2000/01	2005/06	2010/11
Gasoline	Delhi	42.39	49.18	52.12	50.83	50.05
	Calcutta	13.47	11.97	12.02	11.15	10.64
	Mumbai	13.09	12.29	12.75	13.20	13.93
	Bangalore	22.63	26.22	31.18	38.47	49.93
Diesel	Delhi	21.57	26.27	37.29	49.27	61.97
	Calcutta	7.96	8.23	9.73	10.47	10.84
	Mumbai	20.32	24.73	28.18	32.66	37.18
	Bangalore	18.52	29.56	32.03	33.13	36 49
Total	Delhi	63.96	75.45	89.41	100.10	112.03
	Calcutta	21.43	20.20	21.75	21.62	21.48
	Mumbai	33.41	37.02	40.93	45.86	51.11
	Bangalore	41.15	63.24	72.11	84.33	86.42

While analyzing the mix of energy demand by various modes over the next 15 years have revealed that in each of the four cities there will be a gradual phasing out of two stroke engines used in scooters and motorcycles and would be replaced by four stroke technology, more and more catalytic convertor cars which run on unleaded gasoline will be introduced[1] and penetration level of diesel cars and taxis would increase (Annexure 5.6) In 1995/96, cars and jeeps together accounted for over 41% (5% diesel, 35% gasoline and <1% unleaded gasoline) of the total energy demand in Delhi, buses 28%, scooters and motorcycles together 14%, autorickshaws 14% and the balance 3% by taxis (Annexure 5 6). However in 2010/11, energy required by buses would go over 39% of the total energy demand, and that of scooters/motorcycles, autorickshaws and taxis would decline, while that of cars and jeeps would remain at the same current level but with higher dependence on unleaded gasoline and diesel. In Calcutta, cars and jeeps together accounted for nearly 47% (16% diesel and 31% gasoline) of the total energy demand in 1995/96. The share of energy demand by other modes being taxis 19%, autorickshaws 16%, buses 11%, and scooters and motor cycles 7% in the same period. However, in 2010/11, the share of energy demand would continue to be the maximum in cars and jeeps at 44%, 23% taxis, 19% autorickshaws, 8% buses and 6% in scooters and motorcycles. In Mumbai, nearly half of energy is consumed by buses during 1995/96, 16% in cars and jeeps (5% diesel, 10% gasoline and <1% unleaded gasoline), 16% taxis, 15% in autorickshaws and 3% in scooters and motorcycles. Same trend in mix of energy demand in various modes is observed in 2010/11. In Bangalore, over 42% of the total energy is consumed by buses, 25% cars/jeeps (9% diesel and 16% gasoline), 16% scooters and motorcycles, 15%

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[1] except in Bangalore, where it is assumed that no catalytic convertor cars would exist in the coming future.

autorickshaws, 2% taxis during 1995/96. In 2010/11, share of energy demand by buses would go down to 32%, in cars and jeeps to 14% and in scooters and motorcycles to 7%. While energy demand share in autorickshaws would increase to 44% and that of taxis to 3% respectively.

Goods mobility.

In 1995/96, annual diesel demand for freight movement within city limits is estimated to be 0.11 mtoe in Delhi which would decline to 0.07 mtoe in 2010/11. Similarly in Bangalore diesel demand would go down from 0.01 to 0.003 mtoe in the same period. While in Calcutta, diesel demand is expected to increase marginally from 0.012 mtoe in 1995/96 to 0.013 mtoe in 2010/11 and in Mumbai from 0.02 mtoe to 0.03 mtoe respectively.

In all the four cities share of energy demand by the LCVs would increase in the coming years. Current share in energy demand by HCVs is more than that of LCVs. However, in 2010/11, energy demand share of LCVs in Delhi and Bangalore would be higher than that of LCVs (Annexure 5.6).

5.1.1.7. Emissions

Using Eq.(4.4) in the LEAP framework under environmental database module and then linking it up with the energy demand module, annual emissions from different modes and technologies are estimated for each pollutant. Table 5.7 gives the emission factor of the five criteria pollutants viz., CO, HC, NO_x, TSP, SO_2 and Pb with respect to the different range of technologies which are either in use on road or are likely to be introduced in near future. These include, (i) two wheelers (scooters/motorcycles) - two stroke and four stroke; (ii) three wheeler (autorickshaws) - two stroke engine either on gasoline or propane; cars/jeeps - pre 1984 model (like, Ambassador, Fiat, etc.), post 1984 model (Maruti-Suzuki), cars fitted with catalytic convertors (post 1994 model), either on gasoline, diesel and CNG, taxi - gasoline, diesel and CNG . bus - diesel and CNG; and goods - LCV and HCV based on diesel. All new range of vehicles, are assumed to have three way catalytic convertors to check emission of CO, HC and NO_x.

Emission factors in Table 5.7 are used in Eq.(4.4). LEAP detailed output under BAU scenario is presented in Annexure 5.7 which gives estimated annual emissions of these pollutants in the four cities for 1990/91, 1995/96, 2000/01, 2005/06 and 2010/11. The contribution of emission loadings by different modes and technologies are also given in Annexure 5.7.

Table 5.7. Emission factors of Indian vehicles

Technology	Fuel type	Fuel efficiency (km/l)	survey data (IIP) upto 1995/96					
			emission factor (gm/l) based on IIP survey data upto 95/96					
			CO	HC	NO_x	ISP	SO_2	Pb
2wh(2st)	gasoline	44 44	368 85	230 20	4 44	22 22	2 1024	0 15
2wh(4st) in BAU	gasoline	65	539 50	46 80	25 35	5 20	2 1024	0 15
3wh(2st)	gasoline	20 41	250 02	156 14	2 04	10 21	2 1024	0 15
car/jeeppre 84)	gasoline	9 13	272 53	58 47	25 46	3 11	2 1024	0 15
car/jeep(post 84)	gasoline	14 18	134 71	21 27	26 94	3 55	2 1024	0 15
car/jeep(cc)	gasoline	14 8	38 48	4 44	8 88	1 18	2 1024	0
taxi	gasoline	9 43	272 53	58 47	25 46	3 11	2 1024	0 15
car/jeep	diesel	8 86	9 75	2 48	12 40	5 32	8 2630	0
taxi	diesel	8 86	9 75	2 48	12 40	5 32	8 2630	0
bus	diesel	3 3	41 91	6 93	69 30	6 60	8 2630	0
hcv	diesel	5 55	70 49	11 66	116 55	11 10	8 2630	0
lcv	diesel	10	53 90	6 60	93 40	9 00	8 2630	0
S2 Introduce 2wh (4st) with 3 way catalytic convertors, CNG, propane and BOV vehicles								
2wh(4st)-3 way cc for S2	gasoline	-	156 14	46 8	5 07	5 20	2 1024	0
3wh	propane	-	0 000156	0 00468	0 002465	0	0	0
car/jeep	CNG	-	0 000224	0	0 00352	0	0	0
taxi	CNG	-	0 000224	0	0 00352	0	0	0
bus	CNG	-	0 000224	0	0 00352	0	0	0

Note 1/ Sulphur content in gasoline is assumed to be 0 15% (w/w) in 1995/96 and 0 05% (w/w) in 2011/12

2/ Sulphur content in diesel is assumed to be 0 5% (w/w) in 1995/96 and 0 25% (w/w) in 2011/12

3/ Lead content in petrol is assumed to be 0 15 g/l in 1995/96 and would remain same till 2011/12

4/ Specific gravity of petrol is 0 7008 and diesel 0 8263

5/ Specific gravity of petrol is 0 7008, diesel 0 8263, propane (same as for LPG) 0 5602 and CNG 0 80

6/ For 3wh(propane) CO emission factor is 28g/kg, NOx is 4 4g/kg (using 3-way controlled catalytic converters) Source WHO, 1993

7/ For car/jeep or taxi (CNG) same CO and NOx emission factors are assumed as given in 6/ above

8/ For 3wh(propane) HC is Reactive HC HC emission factor is 4 68x10^{-3} kg/m^3 Source. US EPA 1989, FDB of LEAP core database

9/ For bus(CNG), CO emission factor is taken to be same as the diesel bus, For NO_x, it is same as that of a car with catalytic converter

10/ For 2wh(4st) only in S2, 3-way catalytic convertor is assumed which would meet the CPCB 2011/12 target for CO and NOx emission factor would improve by 80%

Source. IIP, 1985, IIP, 1994, Personal communications with Mr. I V Rao, Maruti, Gurgaon Factory in mid 1996, World Bank, 1996 WHO, 1993

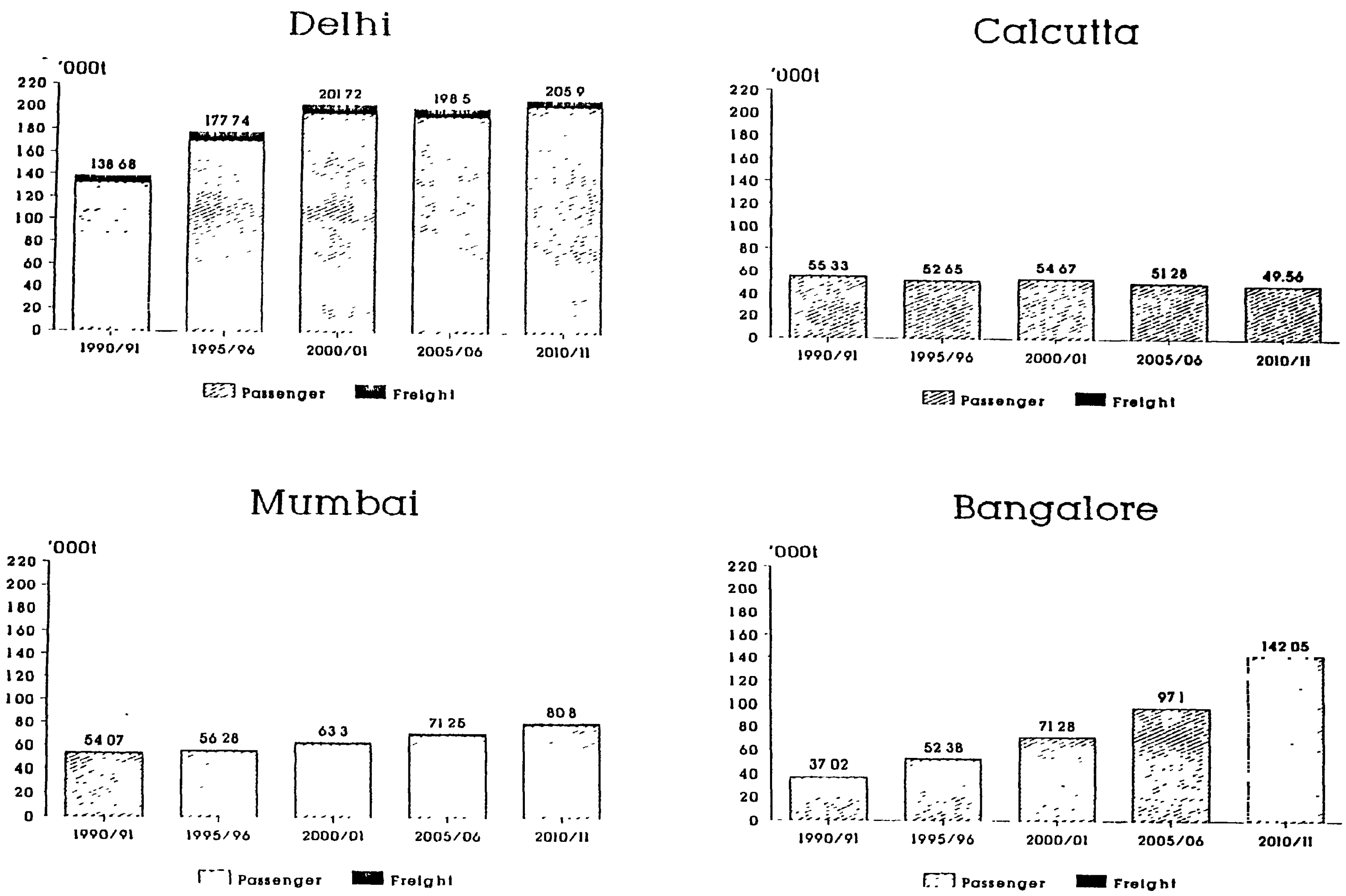


Fig. 5.5 CO emissions in the four cities

Carbon monoxide.

Figure 5.5 gives the annual emissions trend of CO in the four cities. The contribution of emission loadings from goods vehicles in cities are marginal compared to that of passenger vehicles. Annual emission loading of CO happen to be the highest in Delhi relative to the other three cities.

Gasoline driven vehicles contributes majority of CO emissions. In 1995/96, annual CO emissions in Delhi is estimated to be 177740 tonnes (t), which is 28% higher than 1990/91 level and is expected to increase by 16% over the next 15 years. In Calcutta, CO annual emission is 52650 t in 1995/96 which is 5% lower than the 1990/91 level and is expected to decline steadily by 6% over the next 15 years. In Mumbai, it is 56280 t during 1995/96 which is 4% higher than the 1990/91 level and is expected to increase by 44% over the next 15 years. In Bangalore, annual CO emission in 1995/96 is 52380 t which is 41% higher than the emission level in 1990/91 and is expected to increase by 171% over the next 15 years.

Scooters/motorcycles and autorickshaws which are mostly 2-stroke technologies currently contribute nearly 55% of the total CO emission in Delhi (Table 5.8). The corresponding figures for Calcutta, Mumbai and Bangalore are 44%, 50% and 67% respectively. In 2010/11, it is estimated that CO emission contribution from two and three wheelers would further go up to 58% in Delhi, 64% in Calcutta, 62% in Mumbai and 85% in Bangalore, if the present trend of vehicular growth and composition continues. With introduction of catalytic convertor cars from April 1, 1995, in only big metros which include Delhi, Calcutta and Mumbai, contribution of CO emission would decline in future with respect to the current level. Currently, in Calcutta over half CO loading is from passenger cars/jeeps and taxis taken together. This is because average mass emission factor for a typical car fitted with catalytic convertor is 2.6 gm/km which is considerably less than 28.9 gm/km for old (pre-1984) model cars and 9.5 gm/km for post-1984 model cars without catalytic convertors (Table 5.7) While in Bangalore the emission share of CO from cars would increase as cars fitted with catalytic convertors are not introduced in Bangalore city. Buses would contribute increasing share of CO emission in Delhi, Calcutta and Mumbai in the coming years, but would decline in Bangalore.

Table 5.8. Changes in contribution of CO emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	33.1	21.8	38.70	6.4
	2010/11	32.25	25.25	27.33	15.17
Calcutta	1995/96	17.9	26.39	53.14	2.57
	2010/11	19.46	44.92	32.88	2.74
Mumbai	1995/96	14.14	35.75	32.45	17.66
	2010/11	17.45	44.15	16.59	21.81
Bangalore	1995/96	41.55	25.67	22.14	10.64
	2010/11	17.65	66.94	8.15	7.26

Hydrocarbons.

Figure 5.6 gives the annual emissions trend of HC in the four cities. HC emission rates are higher in gasoline than diesel vehicles due to lower combustion efficiency in gasoline engines. Among the gasoline driven two and three-wheelers, two-stroke engines are highly inefficient as compared to the ones with four-stroke engines. Annual HC loading in 1995/96 is 71450 t in Delhi, which is 30% higher than the 1990/91 level, and is expected to increase by about 17% in the next 15 year period. In 1995/96, HC emission in Calcutta is 19830 t, which is 11% higher as compared to 1990/91 level and is expected to increase by 13% over the next 15 years. In Mumbai current emission loading of HC is 21970 t which is about 10% higher with respect to the 1990/91 level and is expected to go up by 57% by 2010/11. Maximum increase in HC emission is expected in Bangalore over the next 15 years. Current emission level is 22960 t which is 48% higher as compared to 1990/91 level, but between 1995/96 and 2010/11, HC emission is expected to increase dramatically by nearly 221%.

About 25 to 40% of the fuel supplied to small 2-stroke gasoline engines in scooters/motor cycles and autorickshaws is exhausted without being burned due to "short circuiting" of fresh fuel-air mixture to the engine exhaust port during the scavenging process. This is inherent weakness of the existing design of 2-stroke engines. Thus, 2-stroke engine powered vehicles are large contributors of unburned HC.

In 1995/96 over 80% HC emission is contributed by scooters/motorcycles (2-wheelers) and autoricksnaws (3-wheelers) in Delhi (Table 5.9). The corresponding figures in Calcutta, Mumbai and Bangalore are 71%, 76% and 86% respectively. Very little efforts have been made in the past for introducing 4-stroke engines in cities. As a result if 2 and

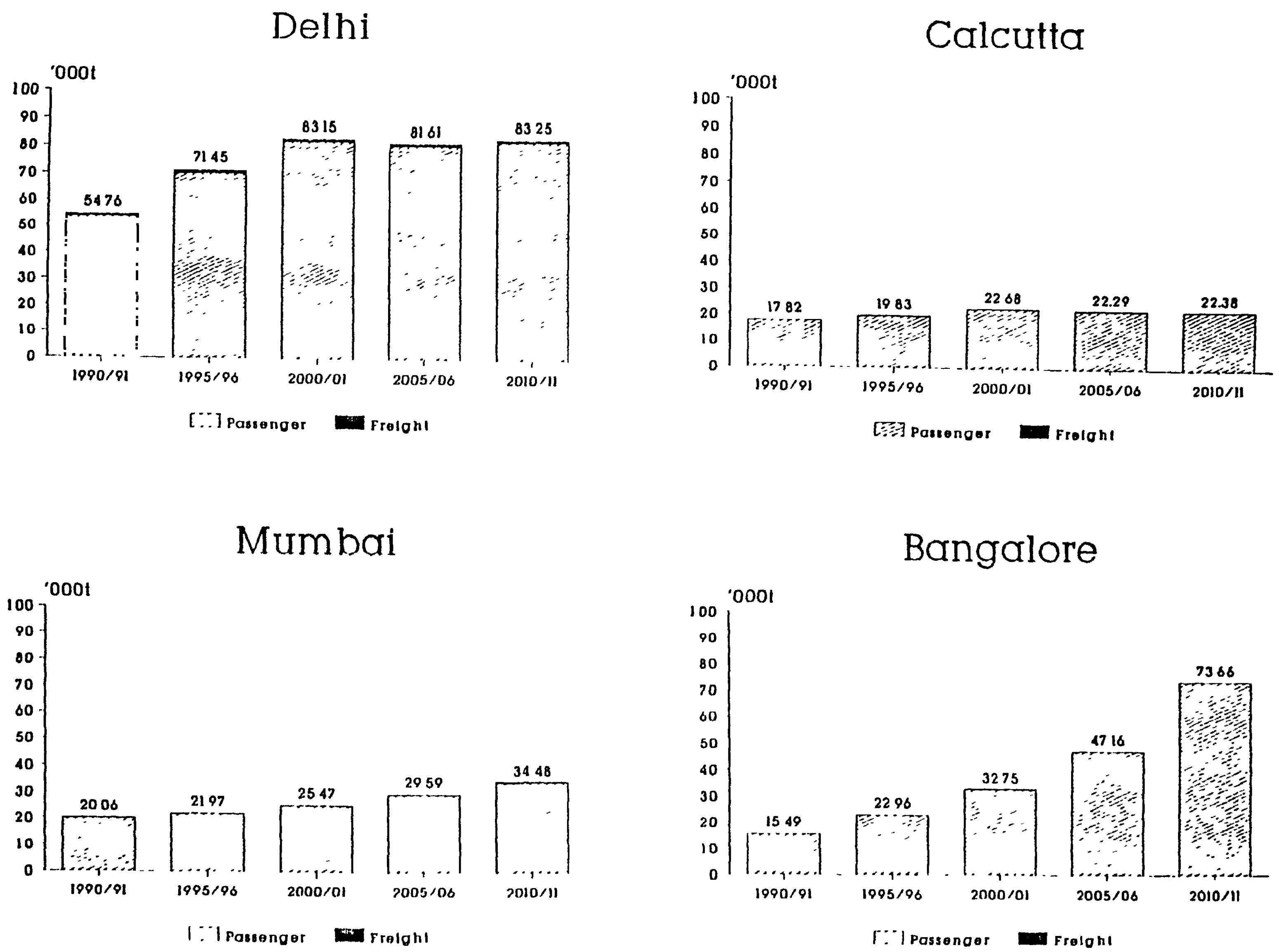


Fig. 5.6 HC emissions in the four cities

3-wheelers with mainly 2-stroke technology continue to grow at the present pace, it is estimated that by 2010/11, HC emission contribution from 2 and 3-wheelers will increase dramatically to 84% in Delhi, 85% in Calcutta, 84% in Mumbai and 95% in Bangalore respectively. The contribution share of HC emission by other vehicles, is also given in Table 5.9.

Table 5.9 Changes in contribution of HC emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	47.68	32.87	16.90	2.55
	2010/11	44.31	39.33	10.26	6.10
Calcutta	1995/96	27.35	43.25	28.28	1.12
	2010/11	23.81	61.28	13.92	0.99
Mumbai	1995/96	19.58	56.27	16.78	7.37
	2010/11	20.76	63.38	7.56	8.30
Bangalore	1995/96	50.38	36.09	9.56	3.97
	2010/11	14.31	80.45	3.11	2.13

Nitrogen oxides.

Figure 5.7 gives the annual emissions trend of NO_x in the four cities. The emission rate of NO_x is higher in diesel driven heavy duty vehicles (like, buses and commercial goods vehicles) because of lower combustion temperatures as compared to gasoline vehicles. In 1995/96, annual NO_x emission is 43930 t in Delhi, which is 32% higher as compared to the 1990/91 level and would increase by 70% over the next 15 years. The emission loading of NO_x would remain fairly stable in Calcutta around 83000 t between 1990/91 and 2010/11. In Mumbai, current loading of NO_x emission is 21550 t which is 18% more compared to 1990/91 level and would go up by 69% by 2010/11. Current loading in Bangalore is 13160 t which is 72% higher compared to 1990/91 level and would go up by 63% over the next 15 years.

Buses contribute nearly 65% of the total NO_x emission in Delhi, 33% in Calcutta, 83% in Mumbai and 79% in Bangalore during 1995/96 (Table 5.10). These shares would further increase in each city by 2010/11. Cars/jeeps and taxis which are mainly diesel driven also contribute significant NO_x emission. In Calcutta, their share of emission is 63% in 1995/96, while the corresponding figures in Delhi, Mumbai and Bangalore are 37%, 15% and 17% respectively. Contribution of NO_x emission from car/jeep and taxis however would decline by 2010/11. Table 5.10 also gives the change in NO_x contribution share in 2010/11 in the four cities. NO_x emission share in the four cities would remain below 4% over the next 15 years.

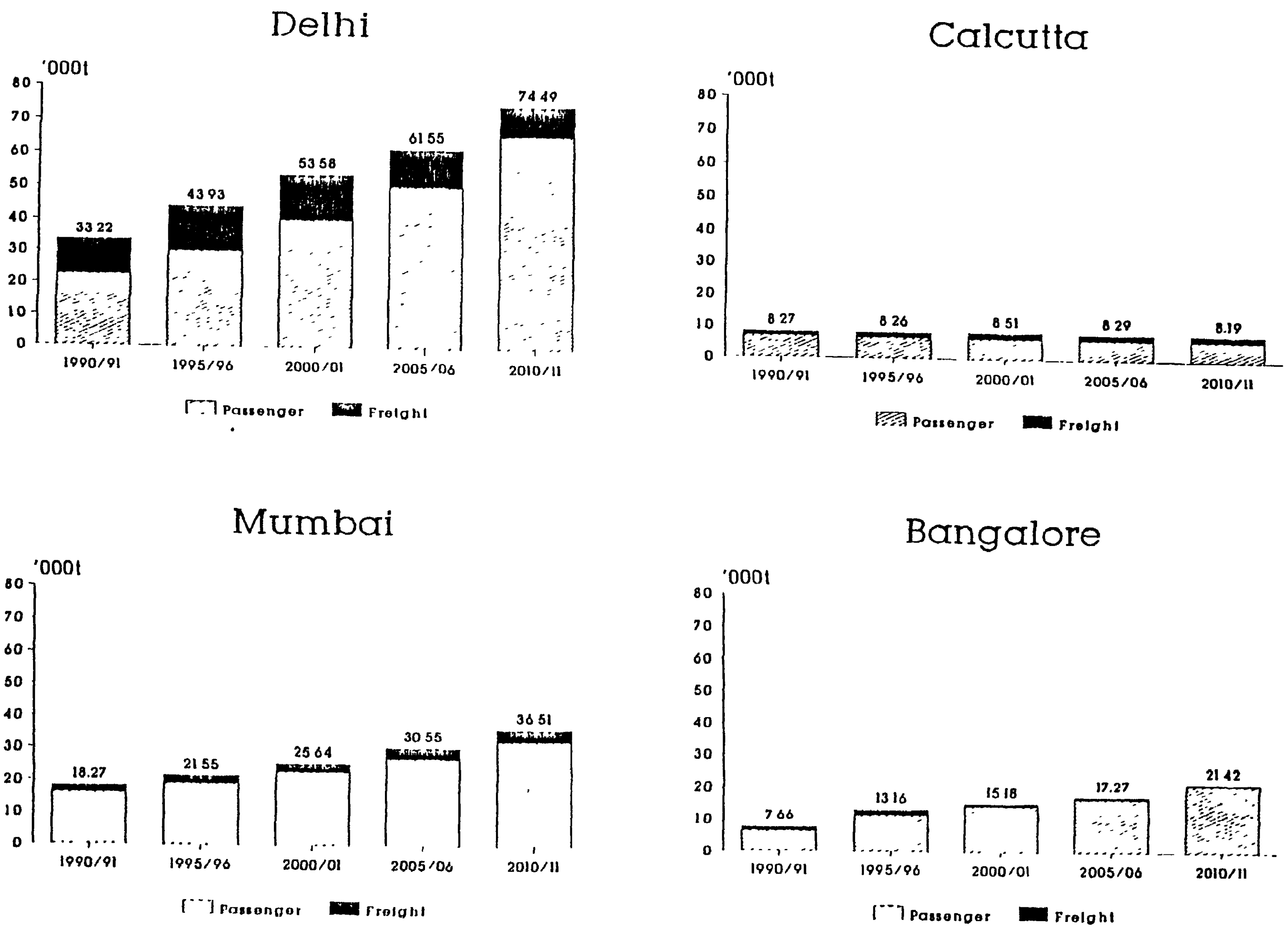


Fig. 5.7 NOx emissions in the four cities

Table 5.10. Changes in contribution of NO_x emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	2.58	1.01	36.66	59.75
	2010/11	1.57	0.65	21.02	76.76
Calcutta	1995/96	2.04	1.66	63.47	32.83
	2010/11	2.32	2.70	61.57	33.41
Mumbai	1995/96	0.68	0.83	15.21	83.28
	2010/11	0.79	0.87	11.73	86.61
Bangalore	1995/96	3.27	0.94	17 02	78.77
	2010/11	3.00	3.68	12.49	80.83

Sulphur dioxide.

Figure 5.8 gives the annual emissions trend of SO_2 in the four cities. Emission rate of SO_2 is higher in diesel than in gasoline vehicles. The concentration of sulphur in gasoline generally lies in the range of 0.05 to 0.25% w/w. For calculation of SO_2 emissions from gasoline vehicles, an average sulphur concentration in gasoline of 0.15% has been taken in 1995/96 and 0.05% in 2010/11. Similarly for diesel, average concentration of sulphur generally lies in the range of 0.5% to 1%. For calculation of SO_2 emissions from diesel vehicles, an average sulphur concentration of 0.5% has been taken in 1995/96 and 0.25% in 2010/11. Further it is assumed that all the sulphur gets converted to SO_2 and is exhausted through the tail pipe.

During 1995/96, total annual emissions of SO_2 is 5180 t in Delhi, which is 35% higher than 1990/91 level and would go over to 116% by 2010/11 (Figure 5.8). In Calcutta the current loading is 1550 t - nearly 8% more than 1990/91 level and would increase to 45% over the next 15 years. Current loading in Mumbai is 3100 t which is 28% more than 1990/91 level, and is estimated to increase by 86% by 2010/11. While in Bangalore, SO_2 emission is 1840 t in 1995/96, which is 72% more compare to 1990/91 level and would increase by nearly 114% in 2010/11.

Table 5.11 gives the changes in vehicular contribution of SO_2 emission. Between 50-65% of the total SO_2 emission is contributed by buses Delhi, Mumbai and Bangalore, while in Calcutta, car/jeep and taxi together contribute nearly 70% emission in 1995/96 and would increase to 76% in 2010/11. Two and three wheelers contribute relatively less SO_2 emission.

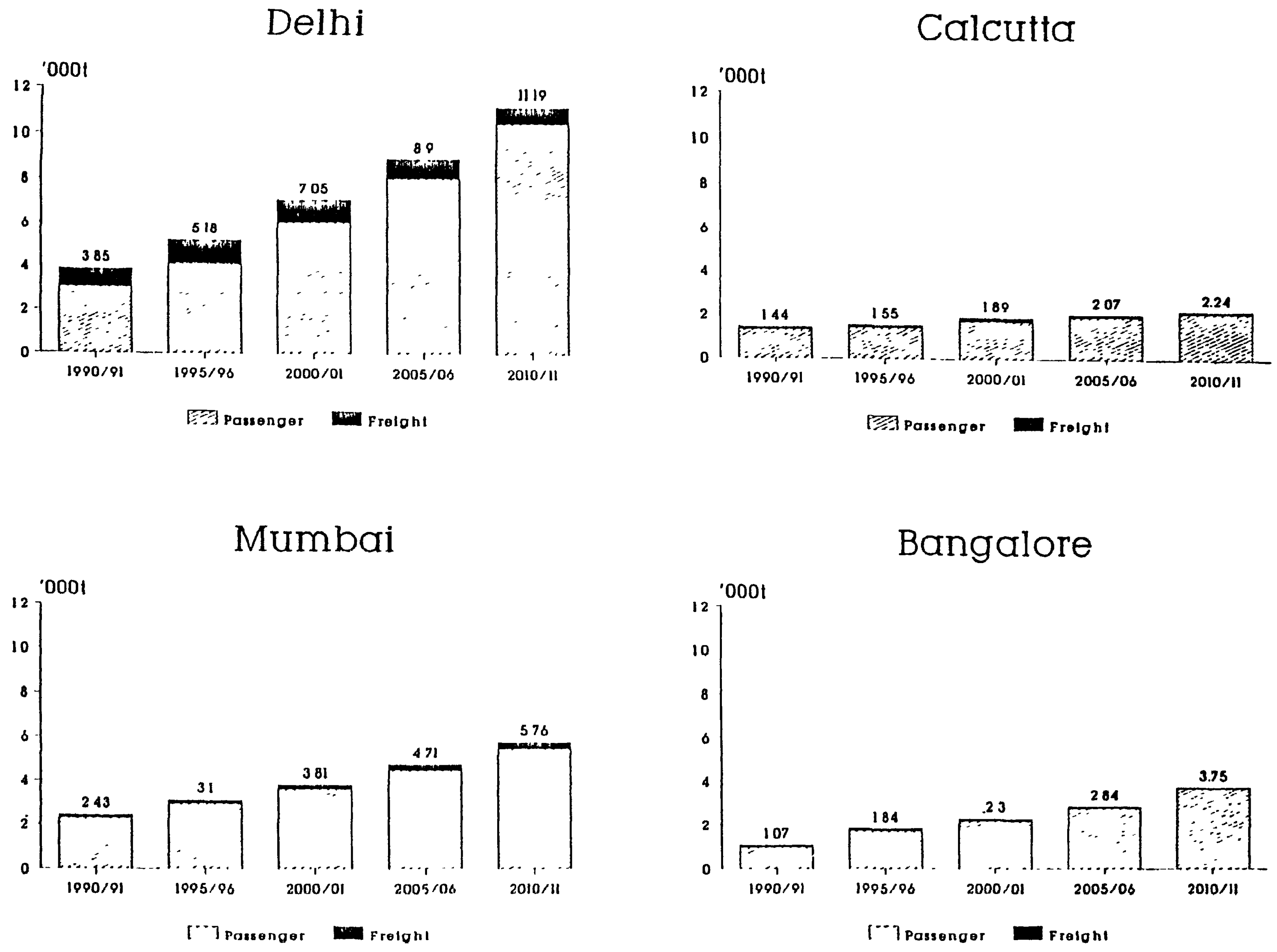


Fig. 5.8 SO2 emissions in the four cities

Table 5.11. Changes in contribution of SO_2 emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	7.65	7.56	32.78	52.01
	2010/11	3.39	4.16	35.26	57.19
Calcutta	1995/96	3.60	8.03	69.99	18.38
	2010/11	2.45	8.67	76.47	12.41
Mumbai	1995/96	1.44	5.64	27.55	65.37
	2010/11	1.34	5.34	31.45	61.87
Bangalore	1995/96	6.76	6.49	23.62	63.13
	2010/11	3.38	21.42	20.72	54.48

Total Suspended Particulate.

Figure 5.9 gives the annual emissions trend of CO, HC, NO_x, SO_2, TSP and Pb respectively in the four cities.Diesel vehicles emit significant TSP as compared to the gasoline vehicles. In 1995/96, annual emission of TSP was 9440 t in Delhi, which is about 34% higher compared to the 1990/91 level and would increase by 51% over the next 15 years (Figure 5.9). In Calcutta, current TSP emission is 2310 t, which is 15% higher than 1990/91 level and would increase by 26% in 2010/11. In Mumbai, TSP emission currently is around 3050 t which is 57% higher compared to the 1990/91 level and would increase by 75% over the next 15 years. In Bangalore, nearly 3050 t of TSP is emitted annually during 1995/96 which is 57% higher compared to the 1990/91 level and will increase to 135% by 2010.

Table 5.12 gives contribution of TSP emission by different modes of passenger vehicles. In Delhi, during 1995/96, about 40% of the total emission is from scooters and motor cycles which would decline to 26% in 2010/11. During the same period, the corresponding figures for scooters and motorcycles are from 24% to 19% in Calcutta, 12% to 11% in Mumbai and from 38% to 14% in Bangalore respectively (Table 5.12). Emission share from three wheelers would increase in Calcutta, Mumbai and Bangalore from 1995/96 to 2010/11, except in Delhi. In the case of cars/jeeps and taxis, emission of TSP would increase in Delhi, Calcutta and Mumbai, however in Bangalore its share would decrease. TSP emission contribution from buses in Delhi would increase from 21% in 1995/96 to 36% in 2010/11. While in Calcutta and Bangalore it would decrease. In Mumbai, buses currently contribute around 45% of the total TSP emission and would remain around the same level till 2010/11.

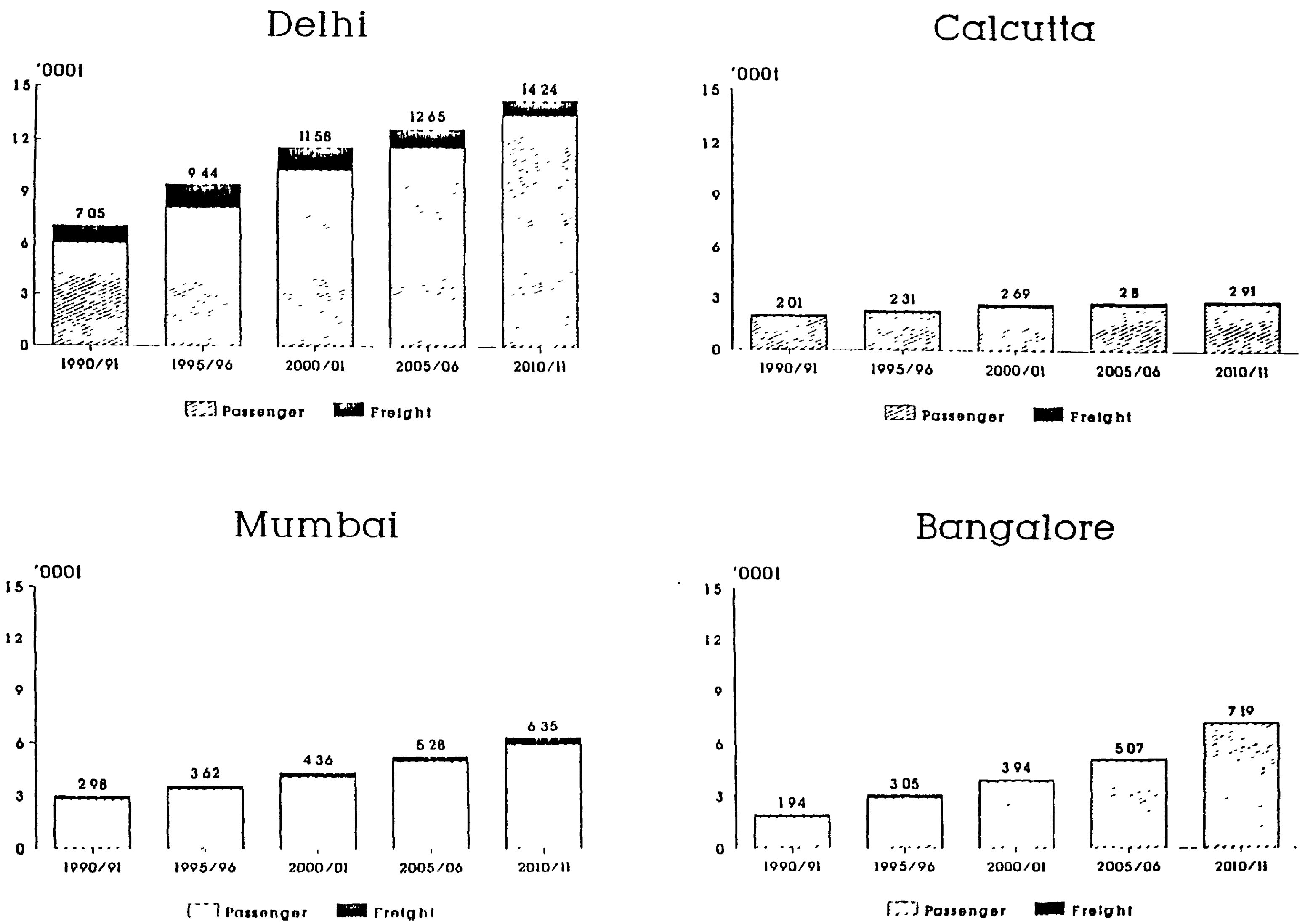


Fig.5.9 TSP emissions in the four cities

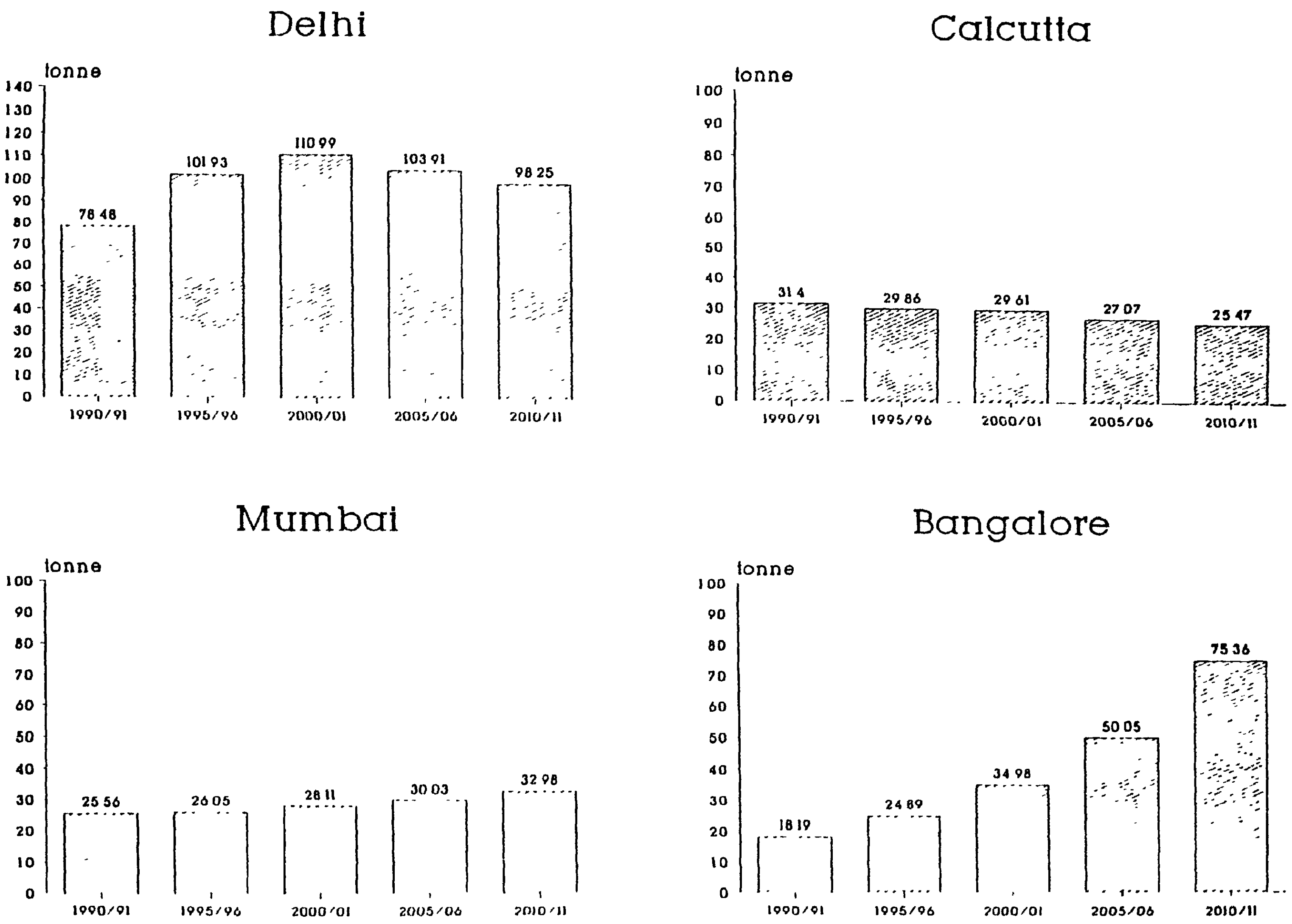
Table 5.12. Changes in contribution of TSP emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	39.86	18.59	20.51	21.04
	2010/11	26.42	15.84	21.94	35.80
Calcutta	1995/96	24.09	25.76	40.45	9.70
	2010/11	18.57	32.30	41.53	7.60
Mumbai	1995/96	12.13	23.54	19.44	44.89
	2010/11	11.48	23.62	19.86	45.04
Bangalore	1995/96	38.52	18.62	13.06	29.80
	2010/11	14.39	54.17	8.77	22.67

Lead.

Figure 5.10 gives the annual emissions trend of CO, HC, NO_x, SO_2, TSP and Pb respectively in the four cities.Pb is only emitted from gasoline vehicles. In 1995/96, annual Pb emission in Delhi is 102 t which is 30% higher compared to the 1990/91 level and is expected to increase till 2000/01 (111 t) and then decline steadily to 98 t in 2010/11. Currently in Mumbai about 26 t of Pb is emitted which is nearly 2% higher than 1990/91 and would steadily increase by 27% over the next 15 year period. In Bangalore, Pb emission which is currently about 25 t would increase by 203% between 1995/96 and 2010 11. While in Calcutta, Pb emission shows a steady decline from 31 t in 1990/91 to 25 t in 2010/11 indicating a 19% drop.

Table 5.13 gives contribution of Pb emission by different modes of vehicles. At present, majority of Pb emission in Delhi and Calcutta are contributed by cars/jeeps and taxis taken together. But its share would decline in 2010/11. With present trend in growth and composition of autorickshaws in Calcutta, Mumbai and Bangalore, Pb emission share would increase considerably to 51%, 63% and 76% respectively by 2010/11.


Delhi

Calcutta

Mumbai

Bangalore

Fig. 5.10 Pb emissions in the four cities

Table 5.13. Changes in contribution of Pb emission by modes (%)

City	Year	Scooter/M-cycle	Auto-rickshaw	Car/Jeep/Taxi	Bus
Delhi	1995/96	22.02	21.77	56.21	0
	2010/11	25.84	31.75	42.41	0
Calcutta	1995/96	12.3	27.43	60.27	0
	2010/11	14.43	51.44	34.13	0
Mumbai	1995/96	11.59	45.22	43.19	0
	2010/11	15.84	63.10	21.06	0
Bangalore	1995/96	33.13	31.80	35.07	0
	2010/11	11.89	75.59	12.52	0

5.1.2. Alternative scenarios

Following scenarios are analyzed to study the impact of different urban transport policy initiatives on energy requirement and emissions due to passenger transportation in the four cities.

5.1.2.1. Scenario 1: Strengthening of public buses

This scenario examines the impact of strengthening of public buses on energy demand and emissions.

In the BAU scenario, the total travel demand in 2010/11 to be catered by bus would be 66% in Delhi. 26% in Calcutta, and 59% in Bangalore (Table 5.4). To strengthen the share of buses in these cities, as compared to the BAU scenario, scenario 1 assumes that by the year 2010/11, with proper policy interventions, the

- share of total travel demand to be catered by bus would increase to 80% in Delhi, Calcutta and Bangalore. While in Mumbai, 80% of the total travel demand would be met by buses alone as per the BAU scenario, so no further changes are assumed in Mumbai.
- share of total travel demand to be catered by cars and jeeps together will reduce by half in Delhi. Mumbai and Bangalore and by one-quarter in Calcutta.
- balance travel demand is split in the ratio 2.1 between two wheelers and intermediate public transport modes (i.e, autos and taxis together).

Table 5.14 gives the change in travel demand share by different modes in the four cities in scenario 1 as compared to the BAU case.

Table 5.14. Changes in travel demand share by different modes in 2010/11 (%)

	BAU scenario					Scenario 1				
	2-wh	3-wh	Car & jeep	Taxi	Bus	2-wh	3-wh	Car & jeep	Taxi	Bus
Delhi	8	5	20	1	66	7	2	10	1	80
Calcutta	10	19	37	8	26	7	2	9	2	80
Mumbai	3	7	6	4	80	11	3	3	3	80
Bangalore	8	25	7	1	59	11	3	3	3	80

5.1.2.2. Scenario 2: Introduction of clean fuel and efficient technology

This scenario examines the impact of introducing the following technological options - in a phased manner between 2001 and 2011 - on energy demand and emissions.

Grounded in this vision of technological options, scenario 2 assumes that by the year 2010/11, with proper policy interventions, following technologies would be introduced for different types of on-road vehicles in the four cities. Table 5.15 gives the assumed changes in technological and fuel mix in 2010/11 in the four cities in scenario 2 compared to the BAU.

- Two wheelers: Share of 4-stroke engines in Delhi, Calcutta and Mumbai would increase from 11-12% in BAU to 50%, while that in Bangalore its share would increase from 20% in BAU to 25%.
- Three wheelers: 15% of its share would be based on propane and 10% based on battery operated in the four cities as compared to the BAU where all three wheelers are based on petrol driven.
- Cars/jeeps: More efficient cars like the ones with catalytic convertors, battery driven and CNG based (excepting Calcutta and Bangalore) will be on road as compared to the BAU case. However, the share of diesel driven cars would reduce to 15% in the four cities
- Taxis: Share of CNG based taxis (excepting in Calcutta and Bangalore) would increase. While that of diesel driven would decrease as compared to the BAU case. All the taxis would be fitted with catalytic convertor in all the four cities
- Buses: Share of CNG (excepting in Calcutta and Bangalore) and battery operated buses would increase as compared to the BAU scenario where all buses are based on diesel driven in the four cities.

Table 5.15. Changes in technological and fuel mix in 2010/11

Modes	Technologies	BAU scenario				Scenario 2			
		Del	Cal	Mum	Ban	Del	Cal	Mum	Ban
2-wh	2-stroke	89	88	88	80	50	50	50	75
	4-stroke	11	12	12	20	50	50	50	25
3-wh	2-stroke	100	100	100	100	75	75	75	75
	Propane	0	0	0	0	15	15	15	15
	BOV	0	0	0	0	10	10	10	10
Car/Jeep	Pre 1984 model	1	12	12	11	0.5	6	6	5.5
	Post 1984 model	35	16	18	49	17.5	8	9	25
	Catalytic conv.	40	35	32	0	54	68	57	51.5
	Diesel	24	37	38	40	15	15	15	15
	CNG	0	0	0	0	10	0	10	0
	BOV	0	0	0	0	3	3	3	3
Taxi	Petrol	5	5	5	5	5	5	5	5
	Diesel	95	95	95	95	70	95	70	95
	CNG	0	0	0	0	25	0	25	0
Bus	Bus	100	100	100	100	80	95	80	95
	CNG	0	0	0	0	15	0	15	0
	BOV	0	0	0	0	5	5	5	5

5.1.2.3. Scenario 3: Strengthening of public buses and introduction of efficient technologies

This scenario integrates the result of scenario 1 and 2 and provide the overall impact on energy demand and emissions.

5.1.3. Results under three scenarios compared to BAU

5.1.3.1. Energy demand

Energy demand for the three alternative scenarios 1, 2 and 3 are estimated using the LEAP framework. Detailed energy demand results of these scenarios are given in Appendix 5.8, 5.10, and 5.12 respectively.

Figure 5.11 gives the trend in total energy demand from 1990/91 to 2010/11 under the alternative scenarios for the four cities. Energy demand results of scenarios 1, 2 and 3 are then compared with BAU and is summarized in Figure 5.12. Following observations form Figures 5.11 and 5.12 could be drawn:

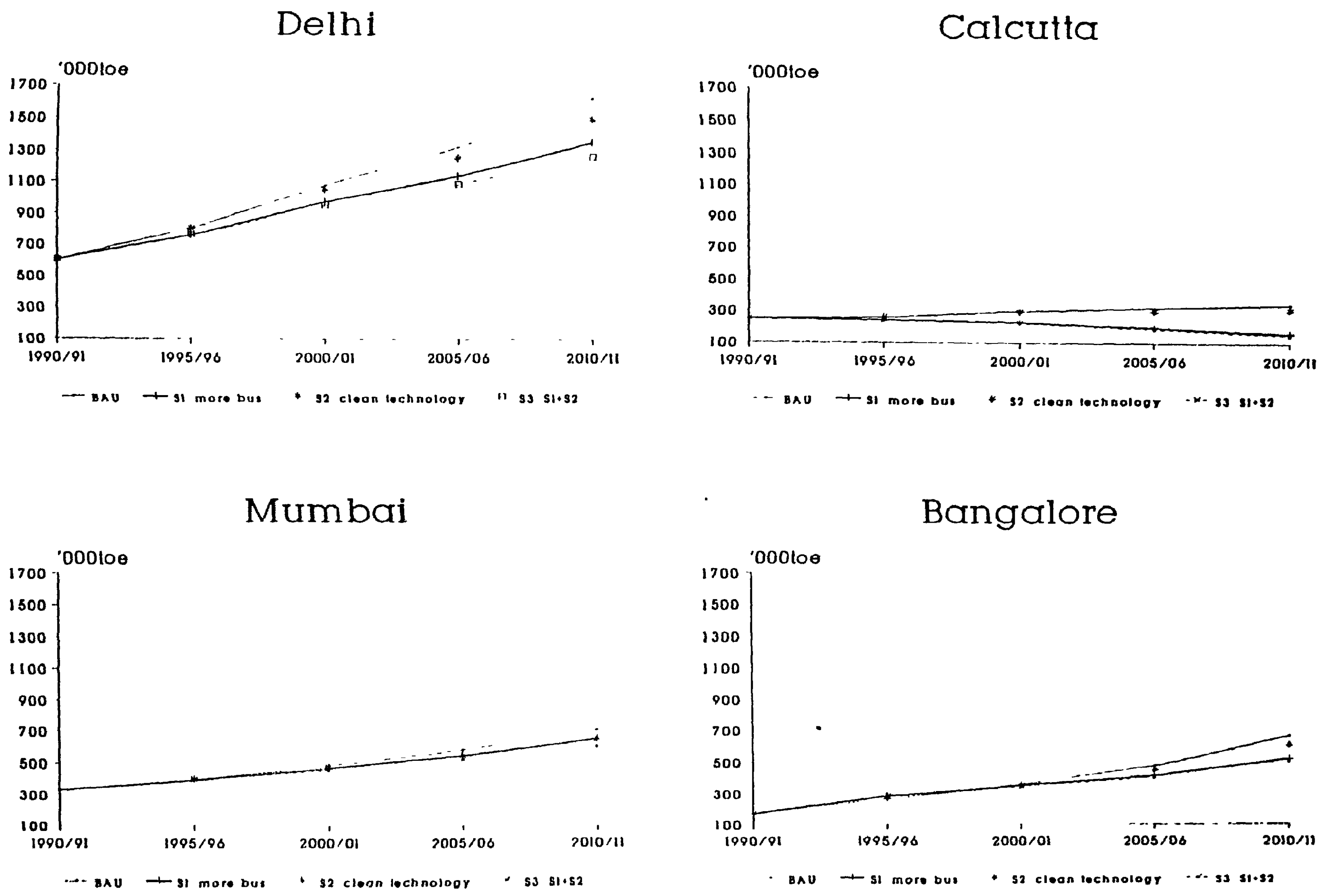


Fig.5.11 Energy requirement in the alternate scenarios

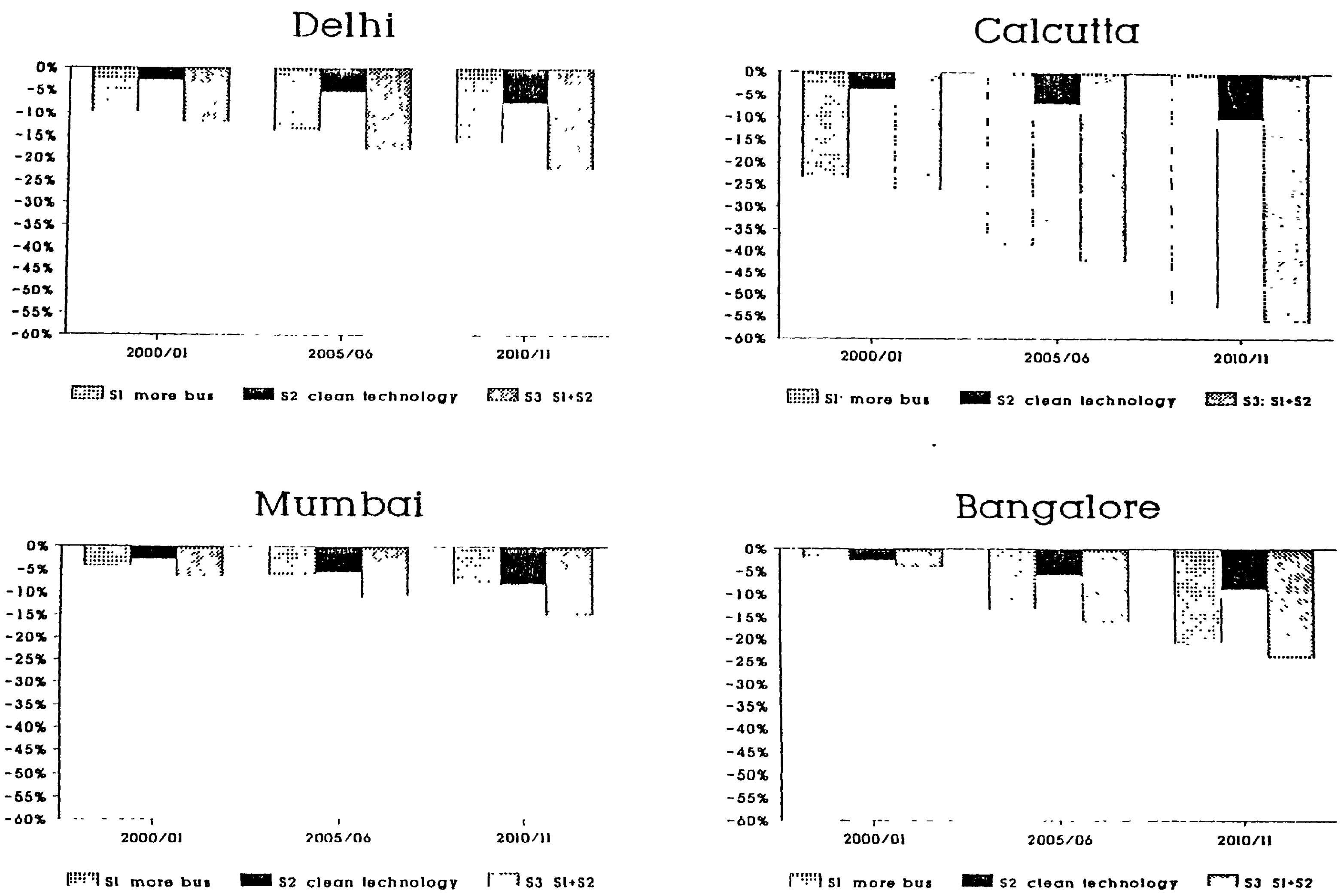


Fig. 5.12 Reduction(-)/addition(+) in energy demand wrt BAU

- Reduction in energy demand would be substantial in future in Delhi, Calcutta and Bangalore with more buses on road as compared to the gradual introduction of clean technologies. However, in Mumbai, since buses are assumed to meet the same level of travel demand in scenario 1 as compared to BAU, but share of cars/jeeps to decline, extent of energy savings would be almost equal in both scenario 1 and 2 compared to BAU.
- Potential for energy savings is over 55% in 2010/11 for Calcutta if the recommendations of scenarios 1 and 2 are in place (i.e., the outcome of scenario 3). While in Bangalore, Delhi and Mumbai, the energy savings potential under scenario 3 is 24%, 22% and 15% respectively. With transport energy requirement in Delhi during 2010/11 under BAU over 2.3 times than Mumbai and Bangalore and nearly 5 times than that in Calcutta, strengthening of mass transport with a view to reduce traffic congestion (scenario 1) and introduction of clean technology (scenario 2) would result in maximum benefit in terms of energy savings in Delhi. Total energy savings potential in Delhi during 2010/11 with more buses and clean technology is 355540 toe which is equivalent to what Bangalore would require during 2000/01 under the BAU scenario. The energy savings potential in Calcutta, Bangalore and Mumbai are 191850, 157900 and 105020 toe respectively. On an annual per capita basis, scenario 3 in 2010/11 would result in 25 kgoe of energy savings in Delhi, 12 kgoe in Calcutta, 8 kgoe in Mumbai and 21 kgoe in Bangalore respectively.
- Energy demand in Calcutta is estimated to increase marginally at the rate of 1.88% annually between from 1995/96 to 2010/11 (Table 5.16). But if recommendations of scenario 1 and 2 are in place, transport energy demand in the same period would reduce at the rate of 3.53% per annum with respect to the present energy requirement in the next decade. While in the other three cities, transport energy requirement in future would increase under alternate scenarios as given in Table 5.16.

Figures 5.13 to 5.16 summarize the structural changes in fuel requirement in the transport sector under alternative scenarios for Delhi, Calcutta, Mumbai and Bangalore respectively. The share of gasoline requirement would decline, while that of diesel would increase in the four cities under the four scenarios. Each of the four cities follow a different trend in fuel mix composition.

Table 5.16. Growth in total energy requirement under alternative scenarios ('000 toe)

City	1995/96	2010/11			
		BAU	S1	S2	S3
Delhi	804.27	1614.33	1348.94	1488.52	1258.79
		(4.75%)	(3.51%)	(4.19%)	(3.03%)
Calcutta	259.31	343.07	162.67	308.29	151.22
		(1.88%)	(-3.06%)	(1.16%)	(-3.53%)
Mumbai	402.05	711.05	653.38	652.92	606.03
		(3.87%)	(3.29%)	(3.29%)	(2.77%)
Bangalore	269.41	663.66	524.70	605.31	505.76
		(6.19%)	(4.54%)	(5.54%)	(4.29%)

Figures within parentheses are the compound annual growth rates between 1995 & 2001.

Delhi

In Delhi, dependence on gasoline requirement will be more than diesel in this decade but this trend would reverse in the next decade (Figure 5.13). With 80% of the travel demand met by buses in 2010/11 in scenario 1, over 70% of the total energy in Delhi would be diesel and the remaining share would be gasoline. Introduction of clean technology in scenario 2) from 2000/01 would result in dependance of CNG, electricity and propane apart from gasoline and diesel. By 2010/11, share of CNG would be 10%, propane and electricity 1% each, gasoline 42% and diesel 46% respectively. Scenario 3 in 2010/11 would result in almost 60% diesel, 28% gasoline, 11% CNG, 1% electricity and <1% propane.

Calcutta.

In Calcutta, requirement for gasoline will be more than diesel in clean technology scenario 2 till 2010/11 (Figure 5.14). However, with more buses diesel demand in the city by 2010/11 will be about 75%. Share of electricity and propane in scenario 2 beyond 2000/01 would be marginal, with no provision for CNG chosen as an alternative. Results of scenario 3 reveals that by 2010/11, gasoline requirement would 28% of the total energy demand, 71% diesel, 1% electricity and <1% propane.

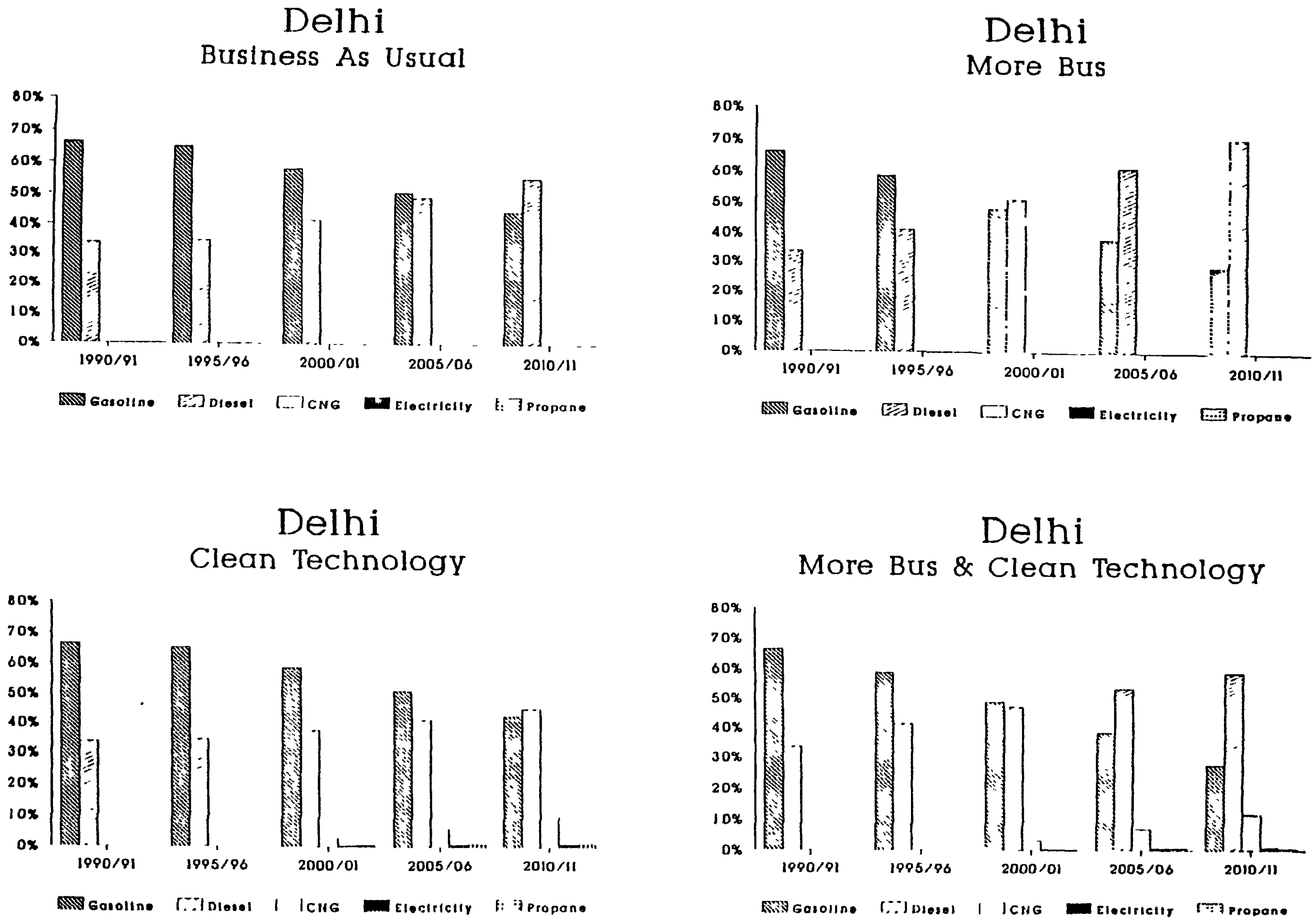


Fig. 5.13 Energy mix pattern under alternative scenarios

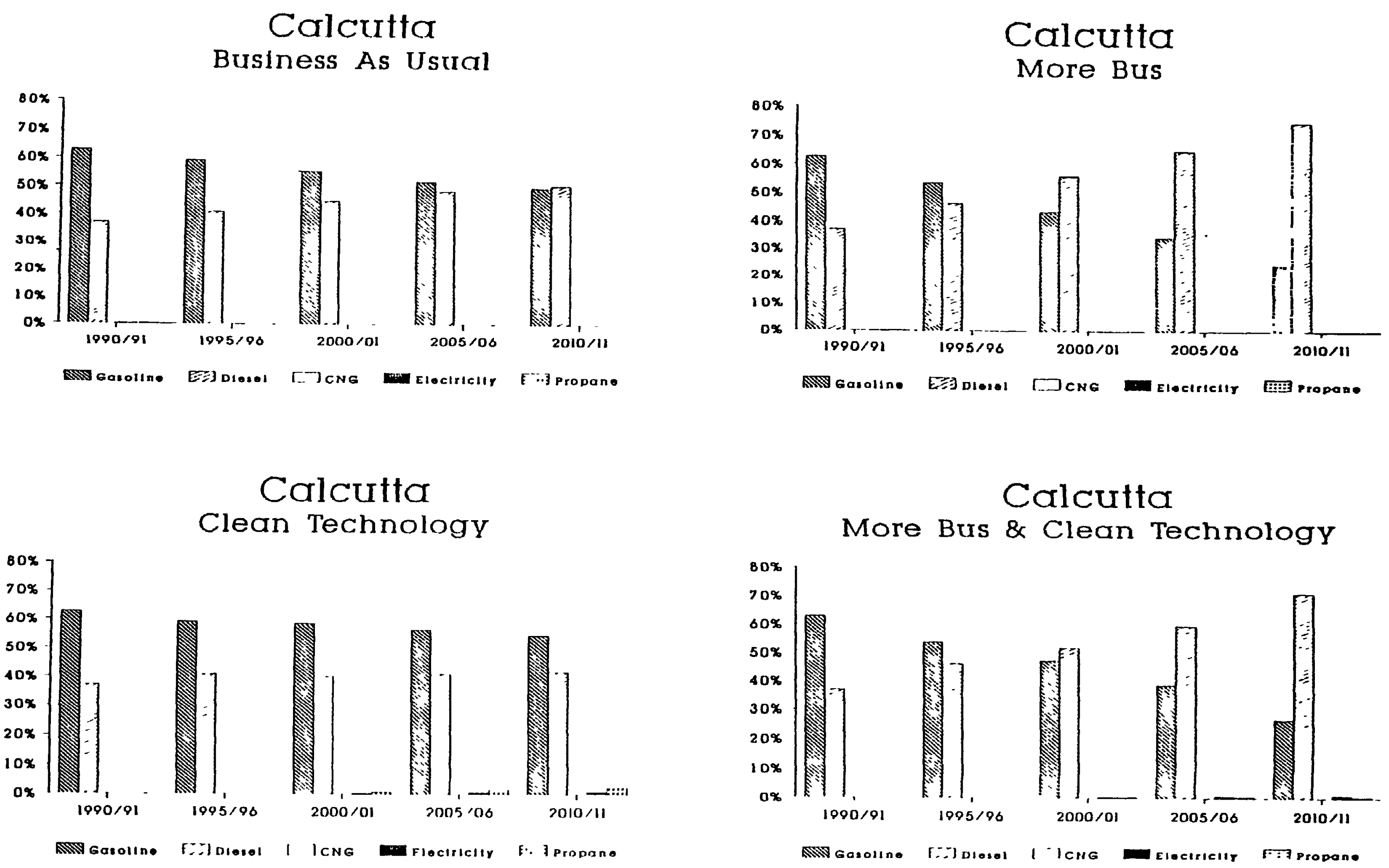


Fig. 5.14 Energy mix pattern under alternative scenarios

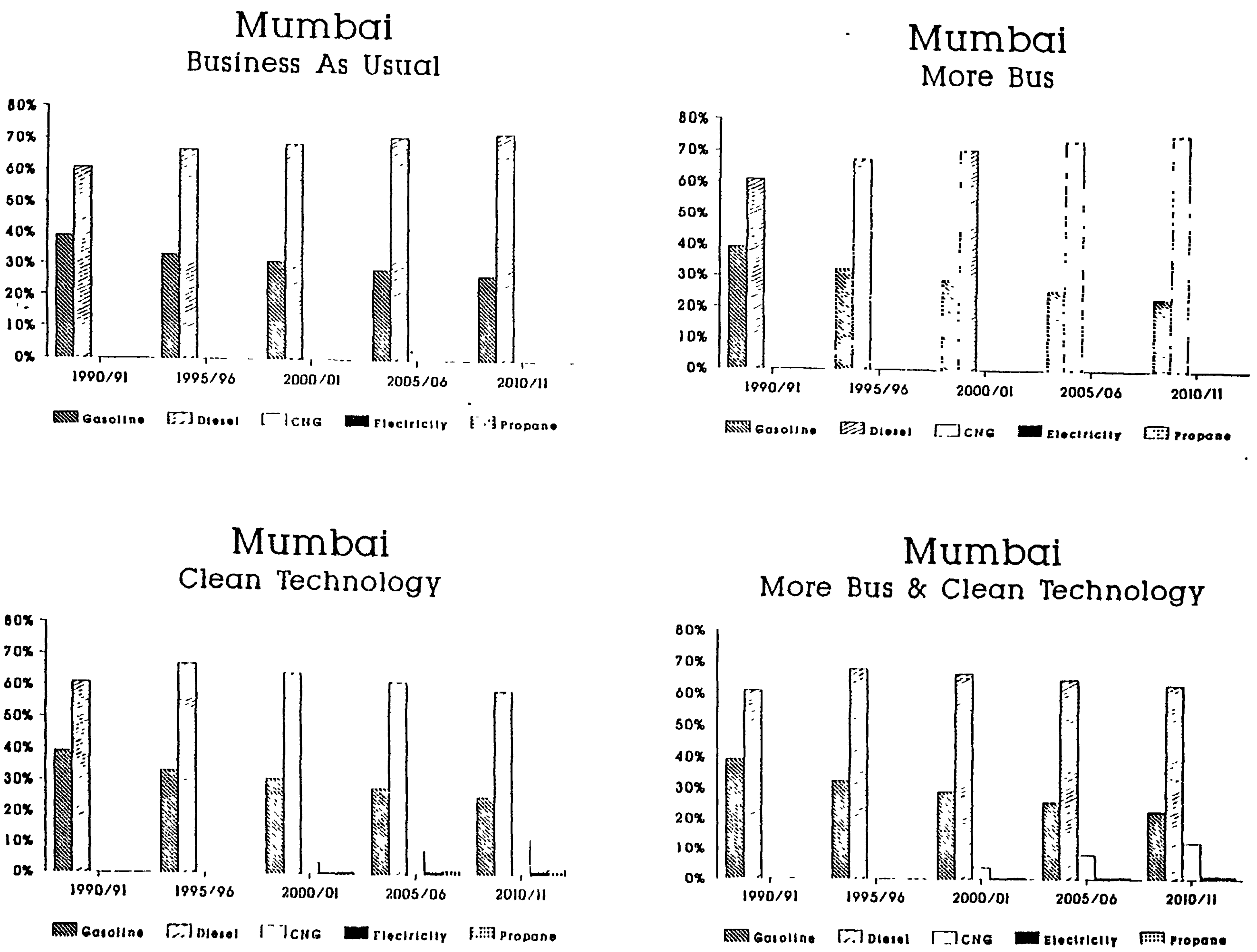


Fig. 5.15 Energy mix pattern under alternative scenarios

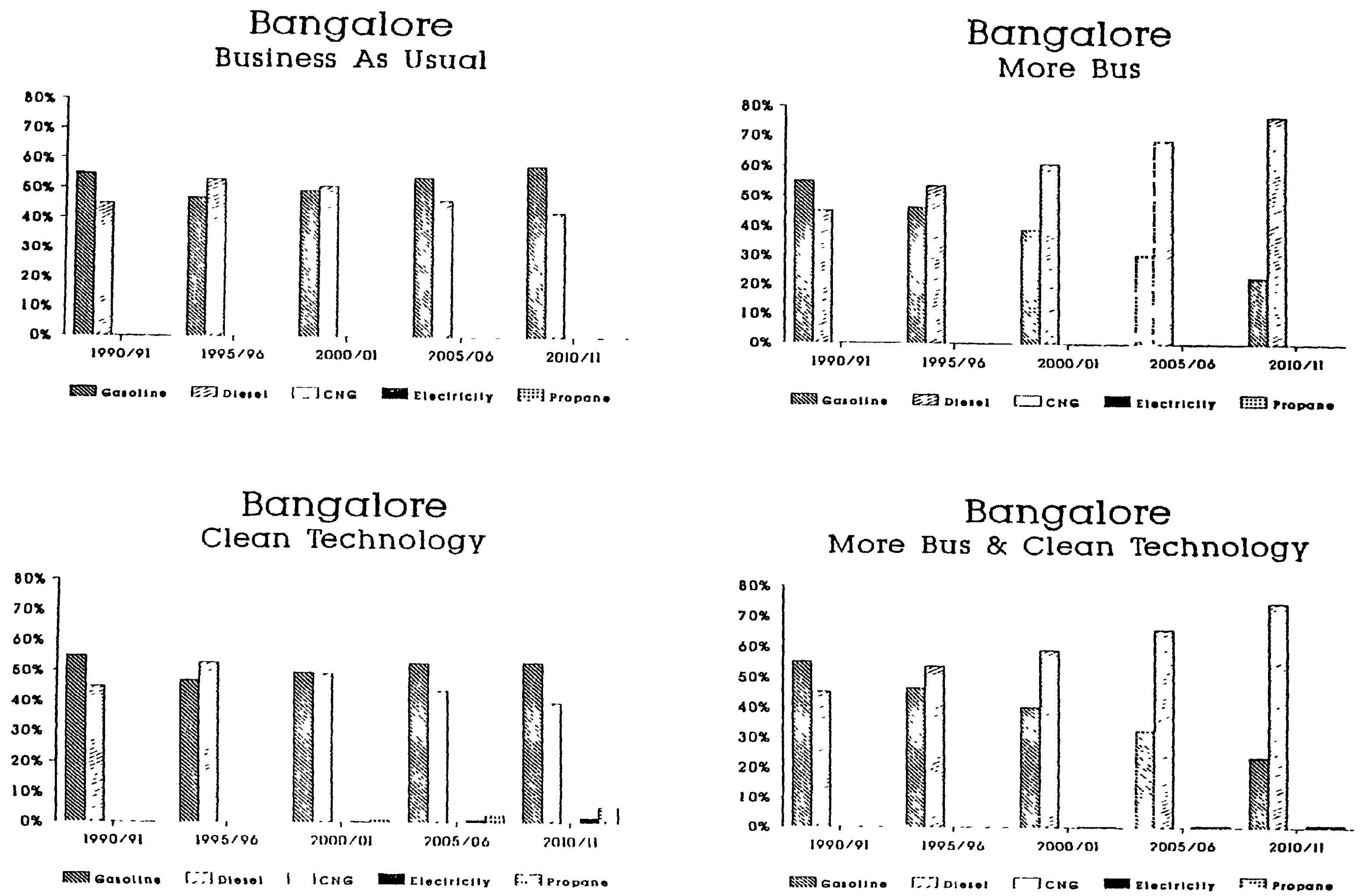


Fig. 5.16 Energy mix pattern under alternative scenarios

Mumbai.

In Mumbai, scenario results do not show any significant deviation from BAU on the mix of fuel requirement under alternative scenarios (Figure 5.15). The current share of diesel is 68% in the city. This is expected to go over to 72% in BAU, 77% in scenario 1, but 59% in scenario 2 and 62% in scenario 3 by 2010/11. Clean technology scenario 2 would result in over 11% dependence on CNG in the city, 2% on propane and 1% on electricity by 2010/11.

Bangalore.

In Bangalore, the BAU scenario shows an upward trend in demand share for gasoline and a reverse trend for diesel, with share of gasoline and diesel being 58% and 42% respectively by 2010/11 (Figure 5.16). But with more buses (scenario 1), share of diesel demand in the city will go up to as high as 78% in 2010/11. While in scenario 2, share of gasoline would be the highest 52% in 2010/11, 40% diesel, 5% propane and 1% electricity, with no provision for CNG chosen as an alternative.

5.1.3.2. Emissions

Emissions loading of CO, HC, NO_x, SO_2, TSP and Pb are estimated for scenarios 1,2 and 3 using LEAP framework. The detailed results are given in Appendix 5.9, 5.11 and 5.13 respectively

Emission results from Appendix 5.7, 5.9, 5.11 and 5.13 are summarized in Table 5 17 which gives the percentage reduction or addition of emissions in alternative scenarios compared to the BAU case in 2010/11. The same table also gives the extent of change in emissions loading between 1995/96 and 2010/11. These results are also depicted graphically in Figures 5.17 to 5.22 for different pollutants for three different years 2000/01, 2005/06 and 2010/11.

Carbon monoxide.

With emission rates of CO from diesel vehicles lower than that of gasoline vehicles because of better combustion efficiencies, more buses on city roads would bring down CO emissions at a much higher level than the clean technology scenario (Table 5.17 and Figure 5.17).

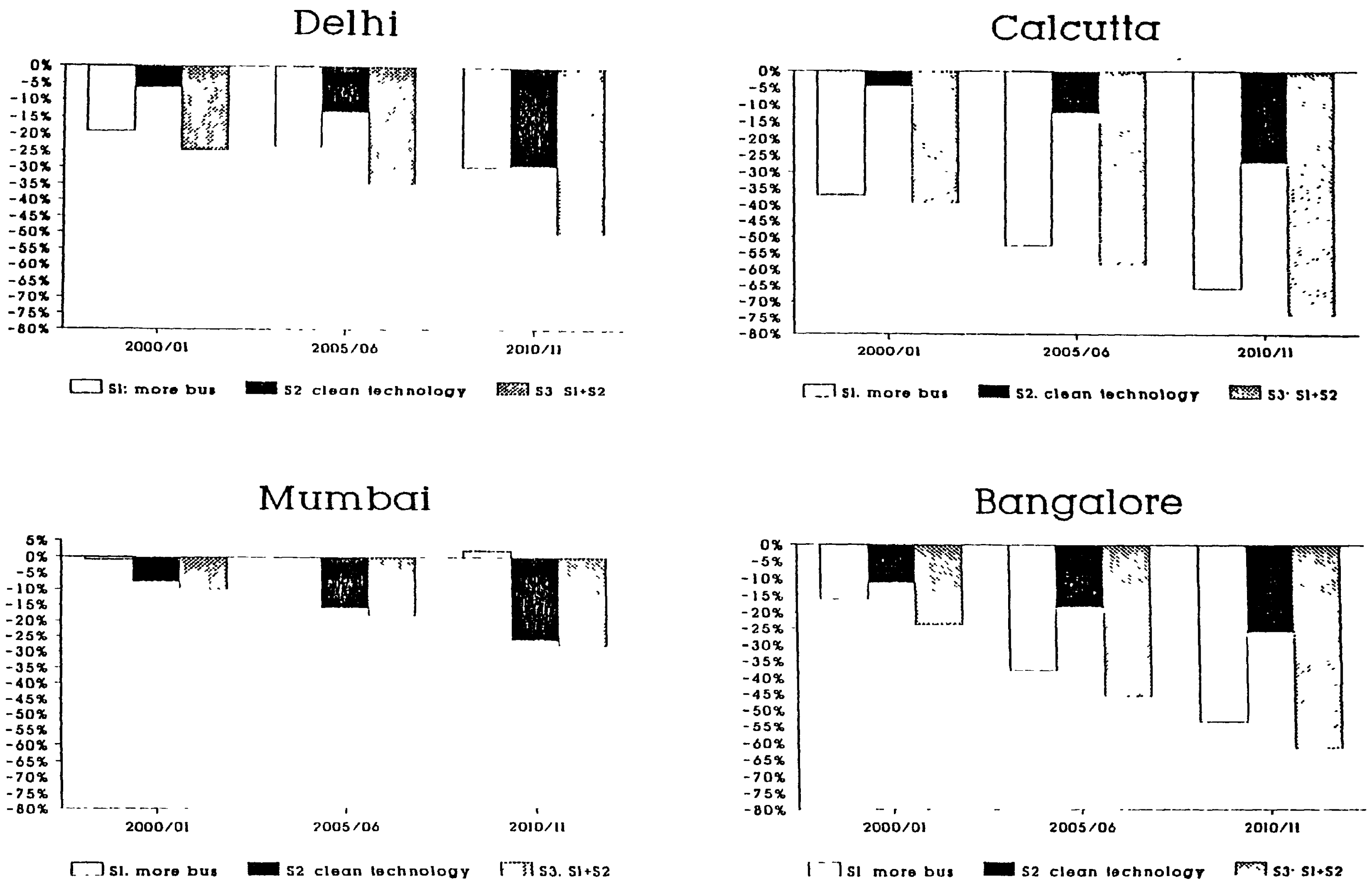


Fig. 5.17 Reduction(-)/addition(+) in CO emissions w.r.t BAU

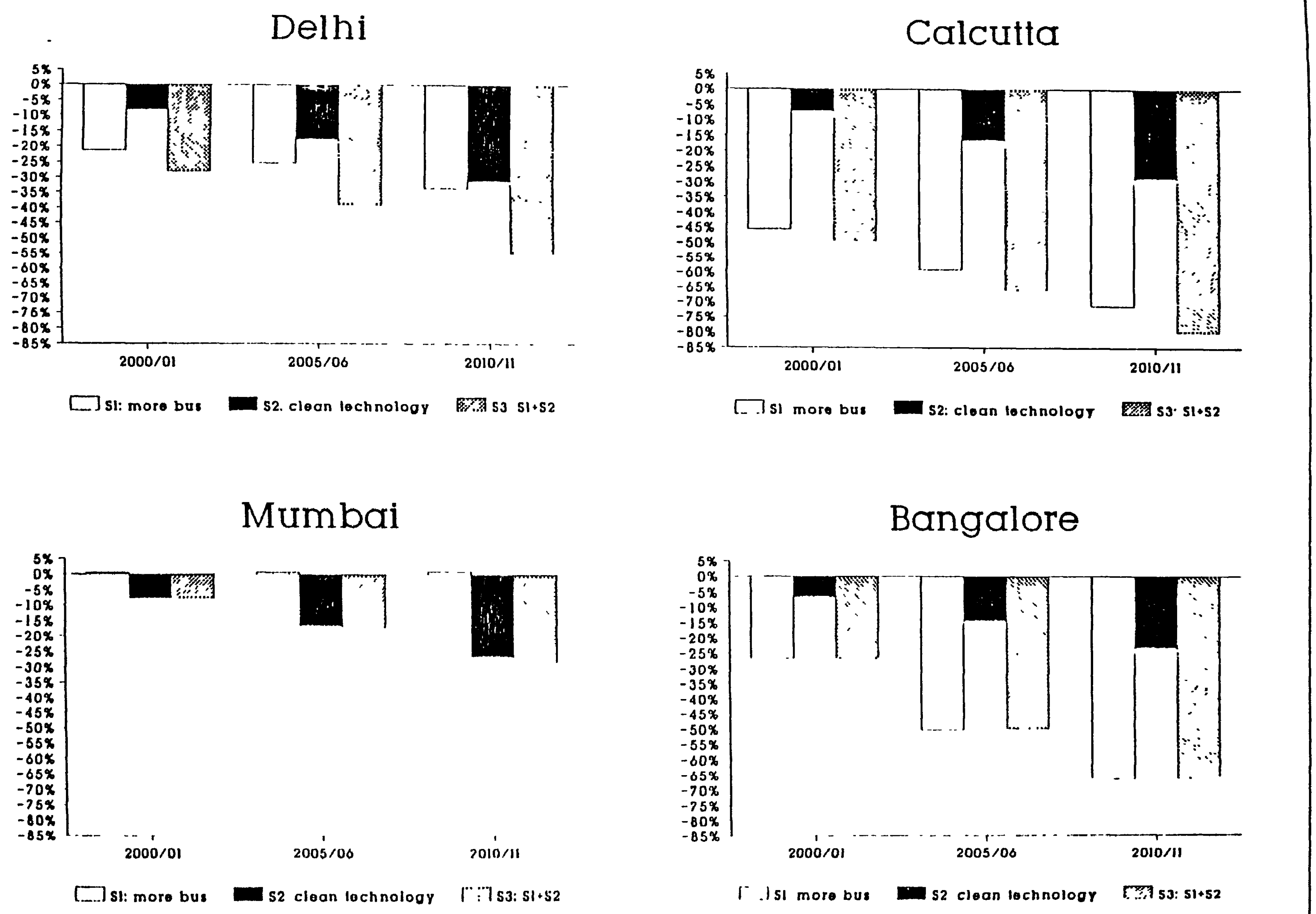


Fig. 5.18 Reduction(-)/addition(+) in HC emissions w.r.t BAU

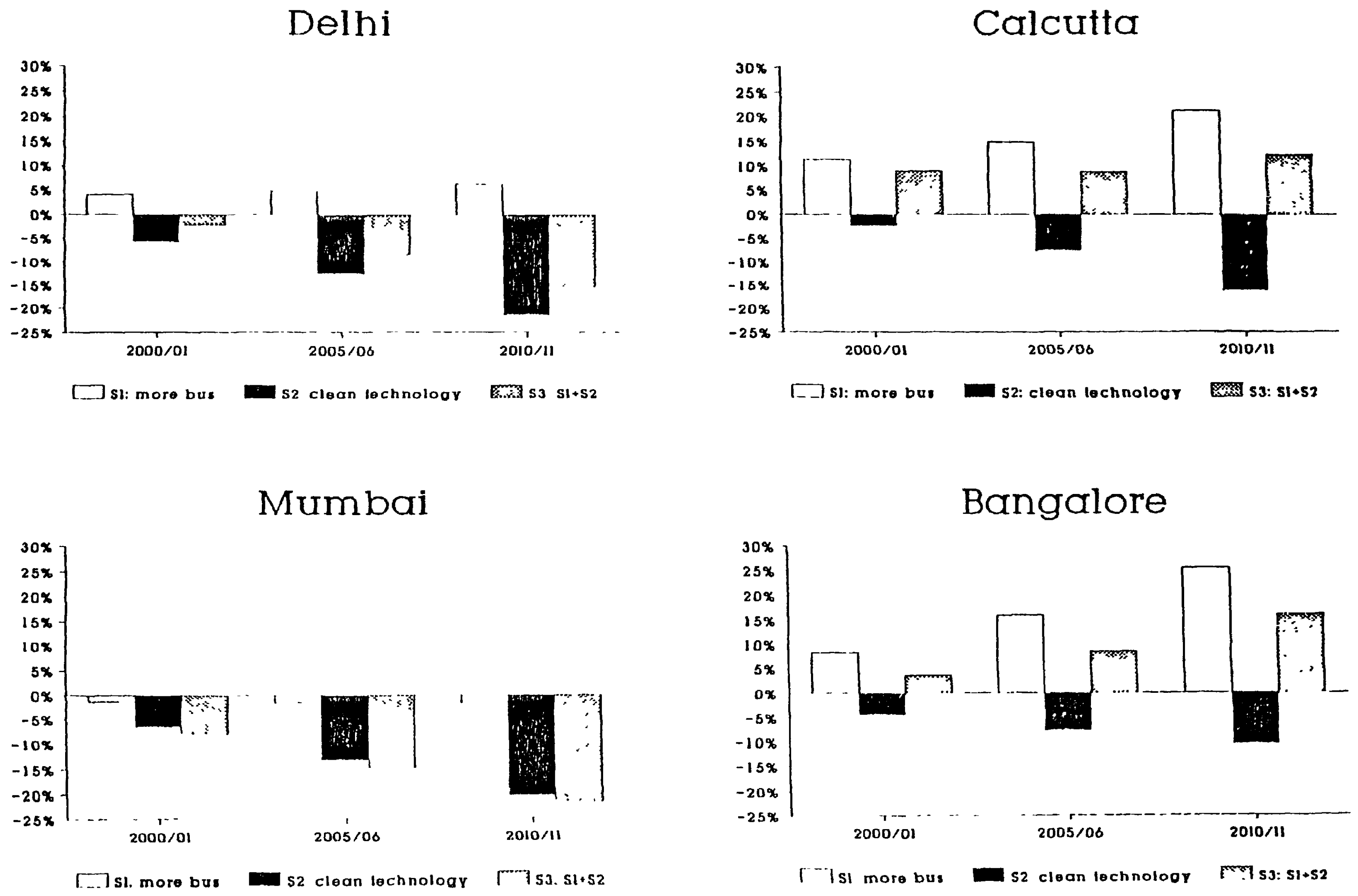


Fig.5.19 Reduction(-)/addition(+) in NOx emissions w.r.t BAU

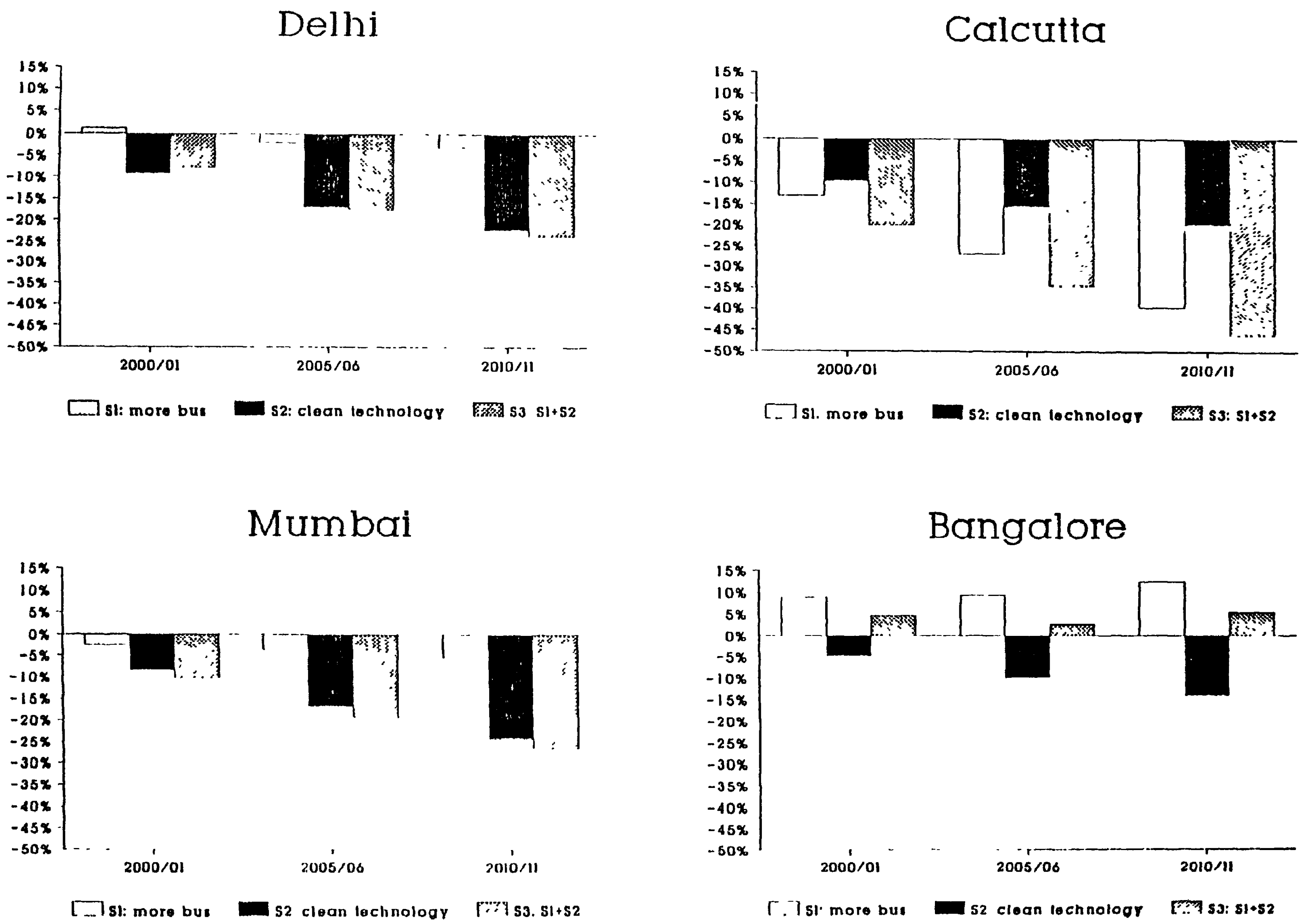


Fig.5.20 Reduction(-)/addition(+) in SO2 emissions w.r.t BAU

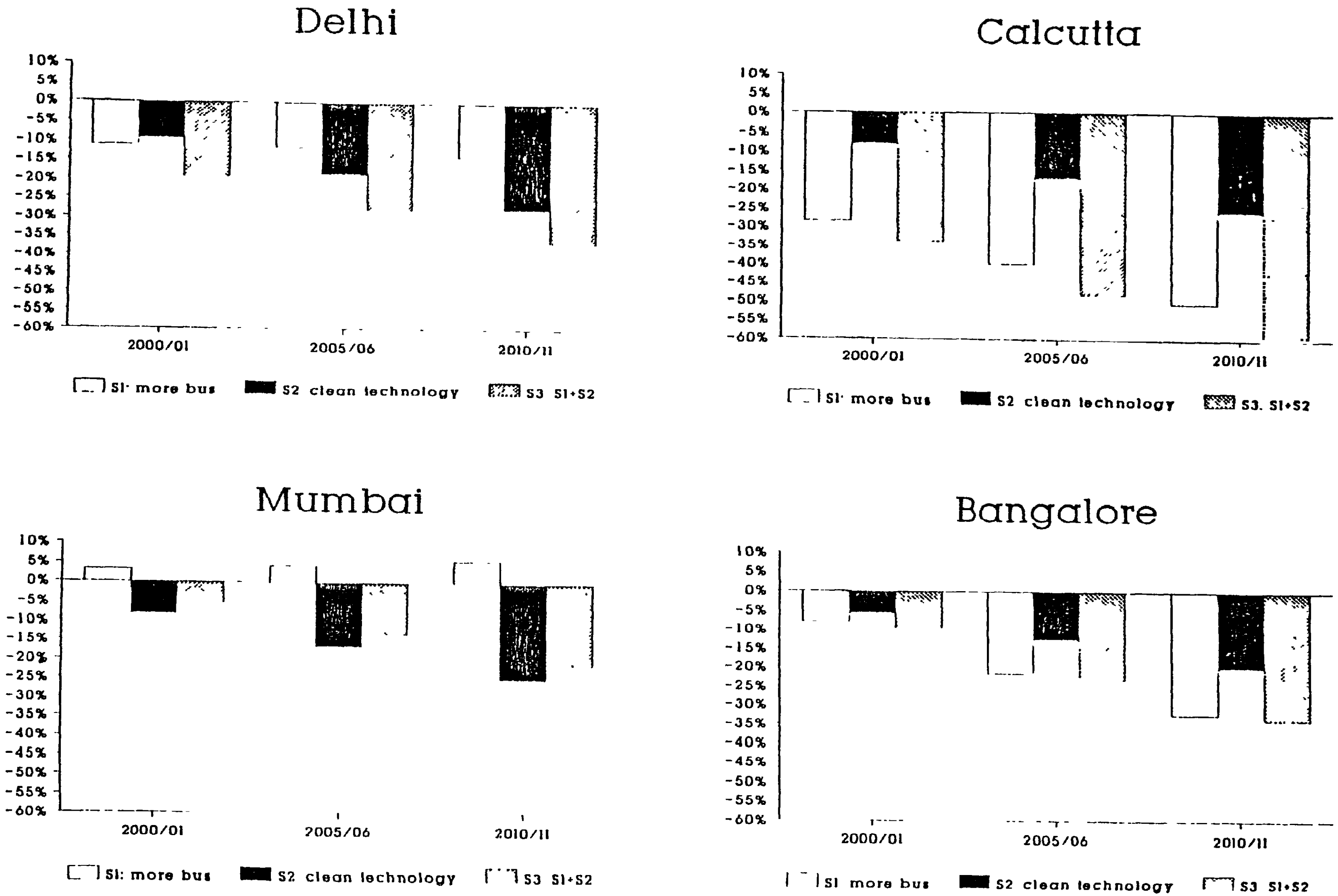


Fig.5.21 Reduction(-)/addition(+) in TSP emissions w.r.t BAU

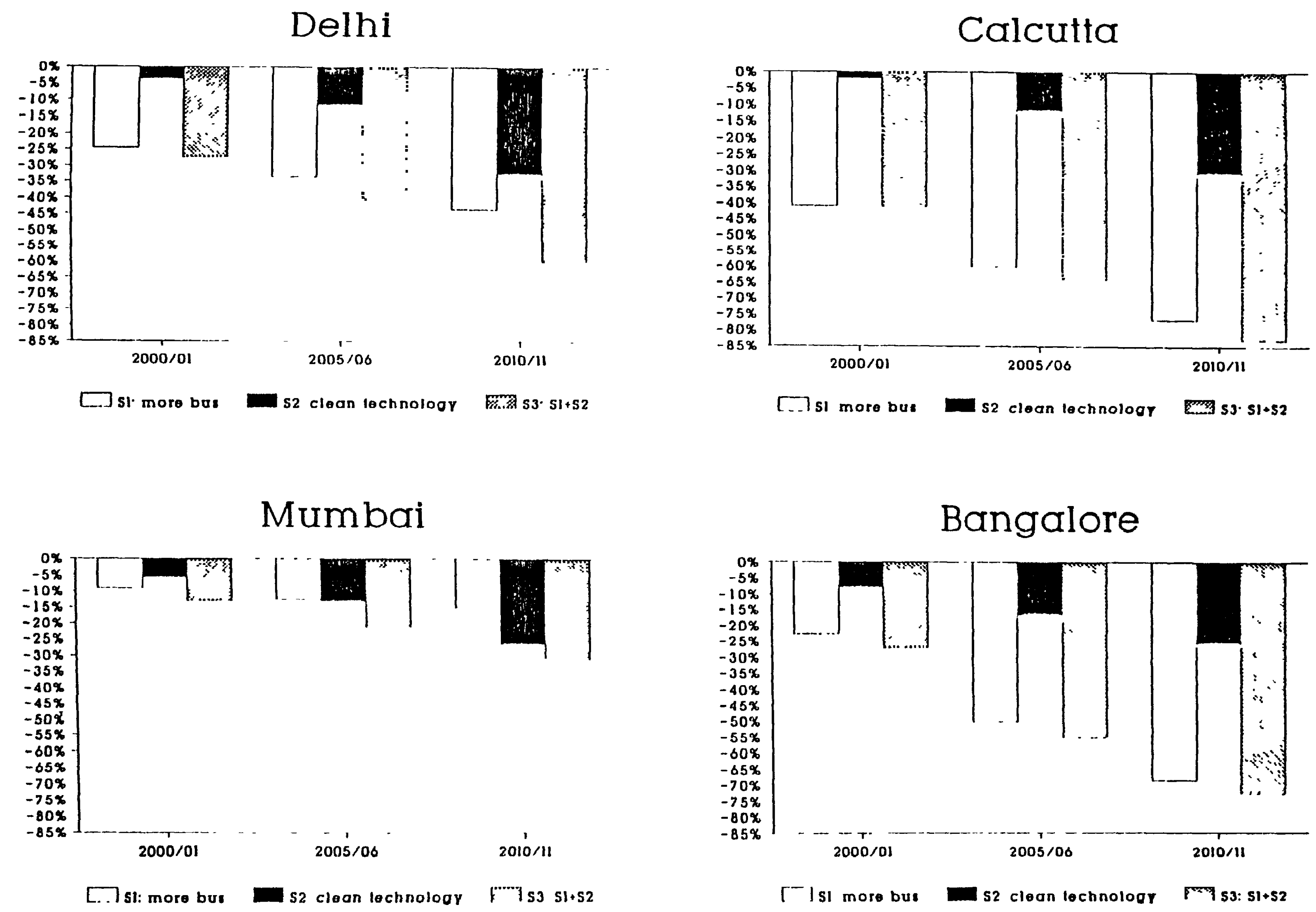


Fig. 5.22 Reduction(-)/addition(+) in Pb emissions w.r.t BAU

Table 5.17. Percentage difference in emissions in alternative scenarios compared to BAU in 2010/11

Pollutant	City	Annual emissions (10^3 tonnes)					Percentage reduction(-)/addition(+)		
		1995/96	2010/11						
		BAU	BAU	S1	S2	S3	S1	S2	S3
CO	Delhi	169.47	200.62	141.25	142.00	100.52	-29.59	-29.22	-49.90
	Calcutta	51.73	48.61	16.67	35.58	12.63	-65.71	-26.81	-74.02
	Mumbai	54.92	78.55	80.28	57.87	56.76	2.20	-26.33	-27.74
	Bangalore	51.39	141.83	65.94	105.01	54.93	-53.51	-25.96	-61.27
HC	Delhi	70.20	82.48	54.81	56.82	37.19	-33.55	-31.11	-54.91
	Calcutta	19.69	22.24	6.40	15.89	4.47	-71.22	-28.55	-79.90
	Mumbai	21.77	34.15	34.47	25.10	24.62	0.94	-26.50	-27.91
	Bangalore	22.81	73.63	24.83	56.31	24.91	-66.28	-23.52	-66.17
NOx	Delhi	30.00	65.56	69.70	51.53	55.54	6.31	-21.40	-15.28
	Calcutta	6.71	6.59	7.99	5.52	7.40	21.24	-16.24	12.29
	Mumbai	19.26	32.71	32.15	26.04	25.63	-1.71	-20.39	-21.64
	Bangalore	11.48	21.05	26.43	18.84	24.44	25.56	-10.50	16.10
SO2	Delhi	4.11	10.49	10.18	8.16	8.01	-2.96	-22.21	-23.64
	Calcutta	1.43	2.12	1.28	1.70	1.14	-39.62	-19.81	-46.23
	Mumbai	2.92	5.46	5.17	4.14	4.01	-5.31	-24.18	-26.56
	Bangalore	1.71	3.72	4.18	3.18	3.92	12.37	-14.52	5.38
TSP	Delhi	8.11	13.39	11.53	9.67	8.49	-13.89	-27.78	-36.59
	Calcutta	2.16	2.76	1.37	2.05	1.13	-50.36	-25.72	-59.06
	Mumbai	3.40	5.99	6.32	4.48	4.71	5.51	-25.21	-21.37
	Bangalore	2.89	7.15	4.84	5.72	4.73	-32.31	-20.00	-33.85
Pb	Delhi	0.10	0.10	0.06	0.07	0.04	-43.59	-32.35	-60.12
	Calcutta	0.03	0.03	0.01	0.02	0.00	-76.60	-30.47	-83.04
	Mumbai	0.03	0.03	0.03	0.02	0.02	-15.22	-26.50	-30.90
	Bangalore	0.02	0.08	0.02	0.06	0.02	-68.54	-25.48	-72.80

Also, if recommendations of scenario 3 are adopted, potential for CO reduction is found to be maximum in Calcutta 74% and least in Mumbai 28% during 2010/11. With appropriate government interventions, recommendations of scenario 3 would reduce CO emissions level even lower than the current loading in Delhi and Calcutta which is 169470 and 51730 tonnes respectively. While, in the other two cities, reduction in emissions will come down to a level which is marginally higher that the current CO emission.

Hydrocarbon

Like CO emission, implementation of scenario 1 recommendations would reduce HC emission more than the introduction of technology scenario 2 in all the four cities

(Table 5.17 and Figure 5.18). This is also because, HC emission from gasoline vehicles are higher than the diesel ones because of low combustion efficiencies in gasoline engines. HC reduction potential is highest in Calcutta (80%) and least in Mumbai (28%) during 2010/11, if recommendations of scenario 3 are in place. Scenario 3 will reduce HC emissions in Delhi and Calcutta more that its current loading level of 70200 and 19690 tonnes respectively. While in Mumbai and Bangalore, HC emissions in scenario 3 is 24620 and 24910 tonnes respectively during 2010/11, which is 13% and 9% higher compared to the current loading level.

Nitrogen oxides.

With more buses on road (scenario 1), emission of NO_x would increase by about 6% in Delhi, 21% in Calcutta and 26% in Bangalore as compared to BAU in 2010/11 (Table 5.17 and Figure 5.19). While with the introduction of clean technology (scenario 2), NO_x emission would reduce by 21% in Delhi, 16% in Calcutta, 20% in Mumbai and 11% in Bangalore compared to BAU in 2010/11. Implementation of recommendations of scenario 1 and 2 together (scenario 3) compared to BAU in 2010/11 would reduce emission by 15% in Delhi, 22% in Mumbai, 16% in Bangalore, while, in Calcutta emission level would increase by 12%.

Sulphur dioxide.

Reduction potential for SO_2 emission is higher in clean technology scenario 2 compared to introduction of more buses scenario 1 in Delhi and Mumbai in 2010/11 (Table 5.17 and Figure 5.20). In Calcutta emission reduction potential is higher for scenario 1 compared to scenario 2 in the same year. While in Bangalore, introduction of clean technology would bring down emission by about 15% compared to BAU in 2010/11, but emission level would increase by 12%. Scenario 3 would reduce SO_2 emission reduction potential by 46% in Calcutta, 27% in Mumbai, 24% in Delhi, but in Bangalore, SO_2 emission would increase in scenario 3 compared to BAU in 2010/11.

Total Suspended Particulate.

In 2010 11, compared to BAU, potential for TSP reduction is very high in Calcutta (over 50%) in scenario 1, while in Mumbai TSP emission level would increase by around 6% (Table 5.17 and Figure 5.21). However, in scenario 2, emission reduction potential in Delhi, Calcutta, Mumbai and Bangalore are 28%, 26%, 25% and 20% respectively. Scenario 3 compared to BAU in 2010/11 would bring down TSP reduction potential by 37% in Delhi, 59% in Calcutta, 21% in Mumbai and 34% in Bangalore respectively.

Lead.

Pb emissions reduction potential in Delhi, Calcutta and Bangalore during 2010/11 are 44%, 77% and 69% respectively compared to BAU with more buses on road, scenario 1 (Table 5.17 and Figure 5.22). While in Mumbai, reduction potential which is about 27% is higher under scenario 2. Considerable reduction potential of Pb emission exists in all the four cities during 2010/11 in scenario 3 compared to BAU - Delhi 60%, Calcutta 83%, Mumbai 31% and Bangalore 73% respectively.

5.1.4. Financial viability of cleaner technologies

This section analyzes the financial viability of introduction of new and cleaner technologies like the battery operated vehicles as an alternative to the conventional three wheeler autorickshaws and a compressed natural gas based passenger cars as an alternative to older model passenger cars.

5.1.4.1. Battery operated vehicles as a substitute to autorickshaws

As mentioned earlier, three wheelers (or autorickshaws) have been growing rapidly in all the four cities. These are less capital intensive, convenient, easily accessible, involves less/minimal waiting time as compared to a bus, reaches the destination fast and less costly when compared with ownership and maintenance of personal vehicles.

CO, HC and Pb are the pricipal pollutants emitted by a conventional three-wheeler. For instance in Delhi, three wheelers (which run on 2-stroke inefficient engines) only constitute only 3% of the total registered vehicles, but they contribute 22% of CO, 33% of HC and 22% of Pb of the total emissions in the city (Annexure 5.3 and 5.7). Phasing out of two-stroke engines is one of the most discussed strategies for mitigating the adverse impacts of road based passenger transportation system among the transport planners in the city

Analysis of financial viability of introducing BOVs as an alternative to the conventional 3 wheelers in India has been carried out. This is because BOVs are comfortable, noiseless and zero emitting as compared to the existing 3 wheelers. Hence, substitution of three-wheelers, by introducing zero emission battery operated vehicles would lead to substantial reduction of the environmental pollution, especially in the large cities like Delhi.

Present net value analysis is carried out for conventional three wheeler and that of its substitute as a BOV. Then ratio of the present net value of BOV to that of a conventional three wheeler is computed with respect to the assumed life span of vehicles (as 9, 12, 15 and 18 years) over different set of discount rates (6, 10, 12 and 15 per cent). If the ratio is less than unity, it would mean that a BOV would be financially viable and attractive over a conventional three wheeler for a given life span and assumed discount rate.

Table 5.18 gives the ratio of the present net value of BOV to that of a conventional three wheeler for a given set of life span and assumed discount rate.

Following assumptions are made for computing the net present value analysis:

- BOV requires recharging time of 6-8 hours after every 100 km of run. Rechanging of battery can be carried out in the night.
- BOV costs Rs 150,000 (which includes the battery cost of Rs 45,000), as compared to a conventional three wheeler which costs Rs 45,000. The battery would have to be replaced every 3 years and there is a battery replacement cost of Rs 45,000 every 3 years.
- The annualised cost for the conventional three-wheeler comes to about Rs 28990 (including the fuel and the O&M cost). The daily output of both BOV and three-wheeler is taken as about 100 kms and considering the vehicles would operate for about 330 days in a year, the annual output is 33000 kms.

Table 5.18. Ratio of present value of 3 wheeler and BOV

Discount	Life span of vehicles			
Rate (%)	9	12	15	18
6	0.977	0 9377	0.9133	0.8969
10	1 018	0.984	0.964	0.950
12	1.038	1.007	0.988	0.976
15	1.067	1.039	1.023	1.014

Annexure 5.14 gives the results of the spreadsheet analysis to obtain Table 5.18. According to Table 5.18, inspite of a BOV which is three times the capital upfront cost compared to a conventional three wheeler, BOV is finacially viable over a conventional three wheeler even within nine years but with a very low discount rate of 6%. But if the discount rates go up, BOV will be attractive over a long run say around 12 years with 10% discount rate.

The higher upfront cost may cause a constraint for promotion of these zero emission vehicles, considering that the ownersip of the vehicles would be private. However, this can be overcome by various incentives like subsidy, loan facilities, adequate public awareness programmes etc.

5.1.4.2. Compressed natural gas vehicles as a substitute to older model cars

Considering the increasing motorization in India and the fast growth rate of petrol/diesel consumption and the consequent environmental degradation, an alternate, lower polluting, technology is always welcome in India. Gas is available in the country and the use of CNG reduces vehicular pollution at the local levels considerably, and also brings down the GHG emissions, thereby, addressing the issue of sustainable development. Conversion kits fitted in vehicles can render them operable on dual-fuel mode (CNG with petrol) and on bi-fuel mode (CNG and diesel). A pilot project was initiated by GAIL (under the Ministry of Petroleum and Natural gas) since December 1992, for conversion of passenger vehicles and a few buses, and their related operationalisation aspects using CNG in Mumbai, Delhi and Vadorara.

During GAIL's pilot project for conversion of petrol vehicles to CNG, five CNG dispensing units were set up in Delhi, a few in Mumbai and 2 in Baroda. More than 1000 petrol-run vehicles have been converted to the petrol-CNG dual fuel mode of operation in these three cities and also some buses on diesel-CNG bi-fuel mode. While the results of petrol-CNG passenger cars are very encouraging, but that of diesel-CNG buses is not at all encouraging. This is because under a typical Indian urban driving cycle a bi-fuel mode does not perform efficiently

A national grid with a pipeline network connecting metropolitan cities is under consideration by the government. However, acceptability of CNG as alternate fuel also depends on the policy decision of the Ministry of Petroleum and Natural Gas for allocation of sustained quantity of CNG to the Transport sector, keeping in view the requirements of sectors such as industry (fertilizer), power plants etc, which are gas-based.

The Government is giving exemption on Customs Duty on the CNG converter kit imported into the country. This has brought down the price of a converter kit by about 15%. The cost of a petrol-CNG kit fitted onto cars is about Rs 30,000/- exclusive of customs duty.

The use of CNG cars would result in substantial reduction of CO, NO_x, SO_2, and lead. The CO_2 emissions would be reduced by 20-25%. However, there would be an increase in the emission of HC and Methane (2-3 times).

The financial analysis of a complete CNG car and that of a older model petrol car is presented in Annexure 5.15. Table 5.19 summarizes the results from Annexure 5.14 by calculating ratio of present values, a CNG car is a financially attractive proposition even with a very high discount rate of 15% with assumed life of cars being 15 years or more.

Table 5.19. Ratio of present value of CNG car and conventional car

Discount	Life span of vehicles		
Rate (%)	15	18	21
6	0.854	0.841	0.831
10	0.878	0.870	0.863
12	0.889	0.882	0.877
15	0.904	0.898	0.895

However, CNG cars have not progressed successfully. This is mainly because of the fact that commercialisation of any new technology is a difficult process, confronted with many technological, economic and market-related barriers. The successful marketing of this technology is a complex phenomenon, affected by the response of three major groups - the customers, the industry, and the government. The vehicle manufacturers are unlikely to produce CNG vehicles without a demonstrable market demand, whereas the demand is stalled by the lack of infrastructure, and the infrastructure will not develop without CNG vehicles. In addition, promotion of this technology also requires a well conceived awareness programme along with scope of financial assistance.

5.2. Power sector

5.2.1. BAU scenario

This section gives the comparative analysis and results of the various aspects discussed earlier for the power sector in the 3 cities - Delhi, Calcutta and Mumbai.

5.2.1.1. Demand projections to examine changing requirements

In order to examine the power situation from the demand side in the 3 cities under consideration, the requirements of each of these cities has been projected upto 2001/02. The Central Electricity Authority (CEA) which is the main planning body, has made projections for requirements of power at the regional and State levels. On the basis of these projections, and the corresponding growth rates, requirements at the city level have been estimated for all the three cities. It should be noted that availability is taken to be synonymous with requirements and unmet demands have not been considered in these estimates.

In case of Delhi the actual and projected generation levels from the 3 thermal power plants are shown in Table 5.20. The CEA has projected the requirements for Delhi to grow at 8.56%, 7.50% and 7.15% over the periods 1995 to 1998, 1998 to 2001 and 2001 to 2002 respectively (*Fifteenth Electric Power Survey*). Since the generation in Delhi is about 50%, in the base case it has been assumed that 50% of the growth is met by plants within Delhi and the rest is met by purchases from the Northern grid.

Table 5.20. Availability of power in Delhi (GWh)

	Indraprastha	Rajghat	Badarpur	IP GT	Local generation	Imports	Availability
1988/89	1105	-	4082	209	5396	2240	7636
1991/92	1478	584	3986	677	6726	3506	10232
1994/95	1115	831	4508	601	7055	8544	15599
1997/98	1264	943	5112	682	8001	11957	19958
2000/01	1411	1053	5709	761	8934	15857	24791
2001/02	1462	1090	5913	789	9254	17309	26563

With these projections, it is seen that the requirements for Delhi indicate that the power availability would increase by as much as 3.5 times in case of Delhi over the period 1988/89 to 2001 02. According to the Northern Region Electricity Board (NREB), these requirements have been overestimated to some extent. However, the requirement levels still indicate a very fast growth rate and it is observed that the intensity of consumption for Delhi vis-a-vis the other cities is seen to be rapidly overtaking that of the other cities.

In case of Calcutta, the power requirement from each of the power plants for the future period is projected to grow at the rates as predicted for CESC's requirements by the CEA. Accordingly, the growth rates are 5% from 1994/95 to 1997/98, 4.4% from 1997/98 to 2000/01 and 4.2% from 2000/01 to 2001/2002 (*9th Plan Power Programme, 1997-2002*). This requirement is expected to meet the needs of the CMA area and CESC would meet the additional requirements by capacity addition in each of the plants. In the base case, it is assumed that the current technologies would continue to be used in each of the plants over time. The power supplied by WBSEB and DVC is considered as imports for Calcutta and the rest is generated locally by the CESC, the supplies of which are dedicated fully to the city of Calcutta. It must be noted however, that the study assumes that the Bandel power plant (under the WBSEB) is located within the city limits for the purpose of calculating emission loading for Calcutta, even though its power is not dedicated to the city's consumption. It is assumed that the CMA region would not face shortages of power till 2002 and the availability is reflective of the requirement for power in Calcutta. As shown in Table 5.21 the availability of power in the CMA is expected to increase by about 1.7 times during the period 1988/89 to 2001/02 in the base case.

Table 5.21. Availability of power in Calcutta (GWh)

	Mulajore	New Cossipore	Titagarh	Southern	Bandel	Kasba	DVC	Availability
1988/89	428	669	1295	-	2503	-	419	5314
1991/92	349	651	1364	694	2048	-	341	5447
1994/95	366	706	1639	996	2304	17	438	6466
1997/98	424	817	1897	1153	2667	20	507	7486
2000/01	482	930	2159	1312	3035	23	577	8518
2001/02	502	969	2250	1367	3163	24	601	8876

In case of Mumbai, the projected power availability for the city is given in Table 5.22. The Tata Electric Companies which are responsible for supplying power to the city of Mumbai have made estimates of the city's requirements in future in order to plan for their capacity expansion. It has been assumed that the level of power drawn from the hydro plants and from the MSEB would remain constant till 2002. The growth in requirement is assumed to be met by the Tata thermal plants located at Trombay. It is seen that the requirement in case of Mumbai has increased by 1.6 times during the period 1988/89 to 2001/02.

Table 5.22. Availability of power in Mumbai (GWh)

	TEC thermal generation	Hydro	Purchases from MSEB	Availability
1988/89	4904	1308	2439	8651
1991/92	6191	1636	1566	9393
1994/95	7015	1335	1968	10318
1997/98	8952	1379	2038	12368
2000/01	10157	1379	2038	13573
2001/02	10581	1379	2038	13997

Source: The Tata Power Company Ltd., Annual Report, 1993-95

Figure 5.23 reveals a comparative profile of total power requirement in the three cities. In 1988/89, Mumbai had the largest requirement (8651 Gwh) followed by Delhi (7636 Gwh), but by 2001/02 Delhi's requirements (26563 Gwh) exceed that of Mumbai (13997 Gwh) by nearly two times. Calcutta has always had the lowest requirement for power (5314 Gwh in 1988/89 and 8876 Gwh estimated in 2001/02).

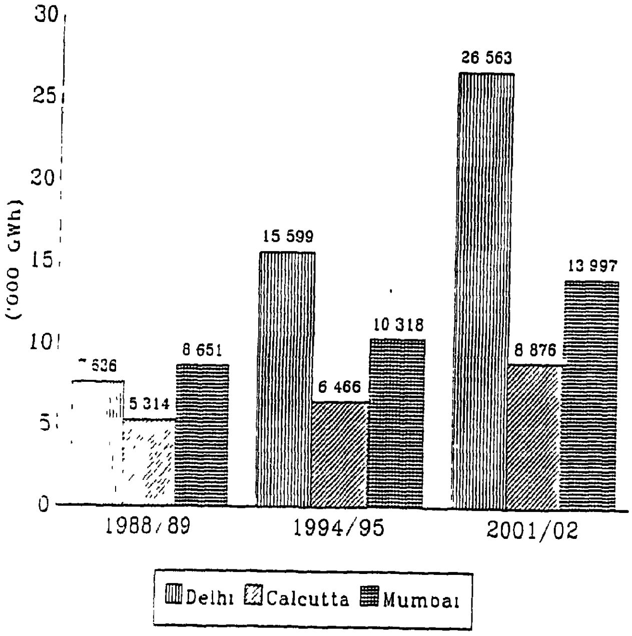


Figure 5.23. Total requirement of power in the three cities

It is likely that the spurt in requirements in Delhi is largely due to the rapidly changing lifestyles in the city. The influence of the media and the effects of liberalisation in the last decade seem to have manifested this boom in energy intensive consumption patterns. Before the 1980s, Mumbai was the most Westernized city with the most energy intensive life style, high rise buildings, posh departmental stores and higher use of electrical gadgets as compared to the other two cities apart from its being the major economic centre for trade and industry. However, since the last couple of decades Delhi too has seen a spurt in commercial activity and lifestyles and consumption patterns have witnessed a distinct boom. The genesis of the *noveau riche* segment has brought about a sea change in the energy consumption patterns in Delhi.

5.2.1.2. Comparison of per capita consumption

In order to examine and compare the levels of power availability across the various cities, per capita generation is a better indicator as compared to the total generation since the extent of industrial usage may be very different in the cities under comparison. Private consumption levels would be more indicative of the consumption intensity of people residing in the various cities. Hence, the per capita power consumption is worked out on the basis of the estimated power consumption for non industrial purposes and the projected population levels for each of the cities over time. In case of Calcutta, the Bandel power plant is assumed to have T&D losses similar to the CESC system and its sales to CMA are added to arrive at the total CMA consumption. Proportional shares are allocated to total consumption for categorization of non-industrial consumption for Calcutta.

Figure 5.24. gives the comparative non-industrial electricity consumption intensities for the three cities. It is seen that Delhi has the highest per capita consumption levels all along from 1988/89 to 1994/95 among the 3 cities. The per capita non industrial consumption has increased in Delhi by more than 43% over this period - from a level of 466 units in 1988/89 to 865 units in 1995/96. The rate of growth of per capita

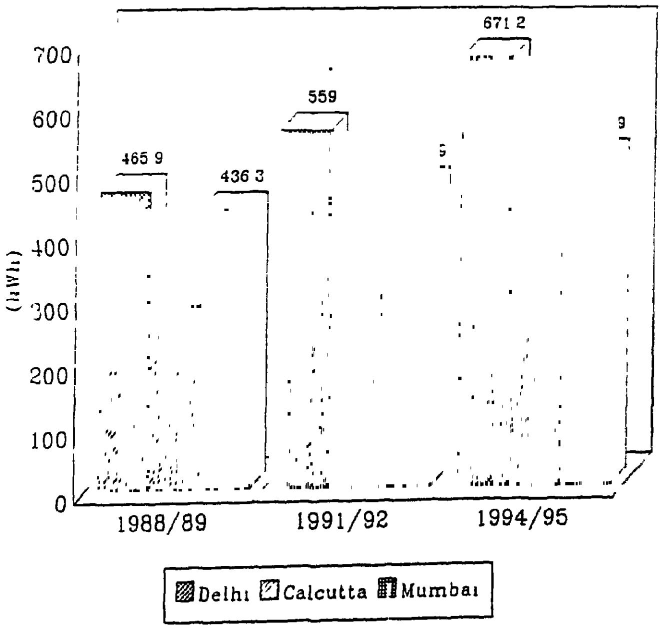


Figure 5.24. Per capita non-industrial consumption of electricity

consumptions is also the highest in case of Delhi during 1988/89 to 1994/95. Calcutta and Mumbai had an annual growth rate of 1% and 2.8% respectively as compared to a growth rate of 6.8% in case of Delhi. In 1994/95, Delhi's per capita consumption is 2.2 times higher than that of Calcutta while it is 1.3 times that of Mumbai.

This trend reveals a rapidly increasing electricity consumption intensity in the city of Delhi which may be attributed to the rising income levels and the changing lifestyle in the capital city in the past decade. It is possible that the variation in per capita consumption might be due to climatic factors and also the standard of living. It is not possible to identify such a correlation with certainty in the absence of data on income wise usage. However, the comparison of the trends across various cities does seem to suggest that a city like Delhi which is hot and dry in summers and comparatively quite cold in winter, might require more electricity for space conditioning rather than in case of Calcutta and Mumbai which are near the coast and therefore have a more humid climate. Use of gadget like geysers, water coolers, air conditioners and room heaters is expected to be the highest in Delhi.

The low levels of per capita consumption in case of Calcutta may be expected due to various factors. Firstly, the inclusion of rural areas within the CMA boundary is expected to have an impact on the per capita consumption levels of power in Calcutta. Secondly, the climate of Calcutta which is relatively humid for most of the year has comparatively lower levels of electricity consumption for space conditioning, water heating, etc. Moreover, the city of Calcutta is also associated with comparatively simplistic and traditional lifestyles which may also account for lower energy intensive lifestyles.

5.2.1.3. Comparison of local generation and purchased power

Another feature in the power sector which has been examined over time and across the various cities is the extent of local generation in these cities. The concern towards power generation within the city limits was felt both in terms of the impact of the resultant air pollution on the population residing within close proximity of these power plants and also in terms of ensuring reliable power supply to meet the requirements of the city. An important point to note in this context is that power planning in India does not entail any location planning with respect to cities or even States. The power plans are made for the region as a whole and the choice of site for the new plant is made on the basis of ease of availability of raw materials and the existence of areas which are not termed as sensitive regions.

Calcutta and Mumbai have had a dominance of power supply by private licensees and the supply position in the past decade has been more reliable than in case of Delhi.

Calcutta as a city was known for its frequent power cuts in the early 1970s, but this position changed after generation for the CMA was taken up largely by the private licensee - CESC. This may be indicative of a better.managed private supply system and may indicate much scope for the SEBs to improve their performance. However, this aspect may not be true for a larger sample size and the indication may be treated with caution.

Another important feature with regard to power supply planning in India is that large cities and important industrial areas are often provided with priority supplies of power and even if the city itself does not have enough capacity of its own, power may be drawn from neighboring areas at the expense of smaller towns and villages to meet electricity requirements in these areas. The example of Delhi is a case in point where the power generated within the city is not sufficient to meet the requirements, but more than 50% of the requirements are being drawn from surrounding areas which also do not have a surplus. It is essential therefore to augment supplies for the entire country and planning in this regard should be considered from a holistic point of view. Therefore, the locational aspect does not seem to hold much concern from the point of availability of reliable power supply if adequate capacity enhancement is planned for to meet the existing demand at the All-India level and power is freely transferred from areas of surplus generation to the deficient regions. However, the locational aspect for power plants does need to be considered with respect to the impact of emissions on the population residing in the vicinity.

Between the period 1988/89 and 1994/95, it is seen that the share of purchased power in case of both Calcutta and Mumbai has decreased while the reverse is true in case of Delhi. The situation for the 3 cities is revealed at a glance in Figure 5.25. Reports of the CESC and the TEC clearly indicate that there is considerable and continuous planning by these agencies to enhance their capacities for making power available within their territories. This may therefore well be the reason of the difference observed when compared to the situation of Delhi. An important point to note in terms of planning especially for Delhi is with regard to the failure in meeting targets. Communication with the various agencies involved. has indicated that the projections on requirements and planning for capacity enhancement etc. are generally done at the Centralized level where the problems of actual operation are not well addressed. Due to such planning procedures, the targeted levels of generation are often not met and slippages have been continuously met by increasing levels of imports from the neighboring states.

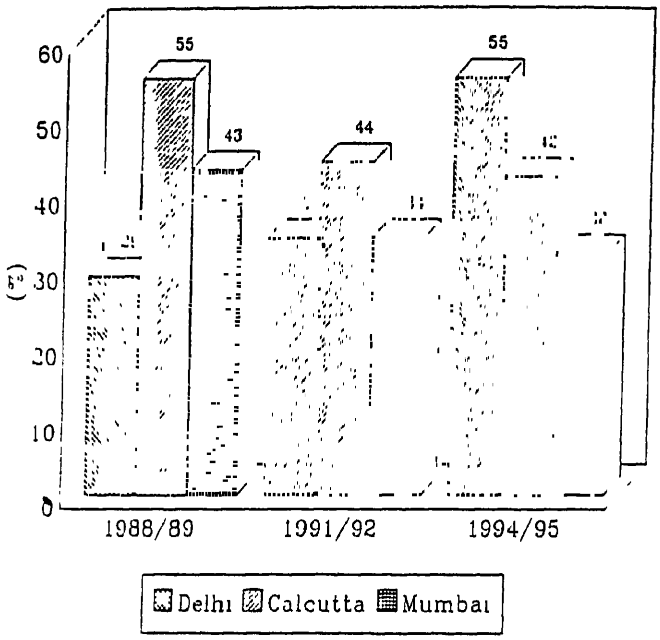


Figure 5.25. Purchase of power

In order to meet its demand, DESU purchases power from various sources in the Northern regional grid, such as certain central sector projects [Badarpur TPS, Singrauli STPS, Baira Siul (hydro), Salal (hydro) and Narora Atomic Power Station], and the neighboring electricity boards (for instance HSEB and PSEB).

5.2.1.4. Fuel consumption and emissions

In order to examine the level of emissions resulting from power generation in each of the cities, we have based the calculations for the past years on the actual generation, the specific fuel consumption and technological details available for each of the plants. Further, for the future years, the generation has been projected on the basis of the growth rates for power requirement as per the CEA forecast and on the assumption that the specific fuel consumption remains constant in the base case scenario. Accordingly, the consumption levels of coal, oil and gas in the power plants located in the 3 cities are calculated for Delhi, Calcutta, and Mumbai and given in Tables 5.23, 5.24 and 5.25 respectively

Table 5.23. Estimated coal consumption in Delhi ('000 tonnes)

	Indraprastha	Rajghat	Badarpur	Total
1988/89	752	–	3429	4180
1991/92	1172	460	3329	4961
1994/95	918	685	3754	5357
1997/98	1041	777	4257	6075
2000/01	1162	867	4754	6784
2001/02	1204	898	4954	7026

Table 5.24. Estimated oil consumption in Delhi (kl)

	Indraprastha	Rajghat	Badarpur	Total
1988/89	35371	–	28204	63575
1991/92	35170	21128	21089	77386
1994/95	22904	7832	11947	42682
1997/98	25972	8881	13547	48400
2000/01	29004	9917	15128	54049
2001/02	30040	10272	15669	55981

Table 5.25. Estimated natural gas consumption in Delhi (million cubic meter)

	Indraprastha GT
1988/89	75
1991/92	244
1994/95	217
1997/98	246
2000/01	274
2001/02	284

The specific fuel consumption in case of Mulajore and New Cossipore plants in Calcutta is much higher (0.9 Kg/KWh) as compared to 0.6 Kg/kWh in most of the other units, since these are old and inefficient plants using the stoker fired technology. However, some of the older units have closed down or decreased their levels of generation so that the overall efficiency of the plants has been improving over time. Based on the specific fuel consumption, and the generation from each of the plants, the quantity of fuels consumed (coal and oil) by the power plants in Calcutta has been computed and is shown in Tables 5.26 and 5.27. For the period beyond 1994/95, the specific fuel consumption has been kept constant till 2001/02. For Kasba and DVC, the actual values were not available and we have therefore assumed that the efficiency of these plants is similar to that of the WBSEB plant (Bandel).

Table 5.26. Estimated coal consumption in Calcutta ('000 tonnes)

	Mulajore	New Cossipore	Titagarh	Southern	Bandel	Kasba	Total
1988/89	380.9	595.4	686.4	0.0	1276.6	0.0	2939.3
1991/92	328.1	611.9	818.4	416.4	1208.5	0.0	3383.3
1994/95	344.0	663.6	983.4	597.6	1359.5	10.4	3958.5
1997/98	398.6	768.2	1138.4	691.8	1573.8	12.0	4582.8
2000/01	453.2	874.2	1295.4	787.2	1790.8	13.7	5214.4
2001/02	472.2	910.9	1349.8	820.3	1866.0	14.2	5433.4

Calcutta does not have any gas based units and coal is the major fuel used. This largely stems from the fact that gas is not available around this region, while the Eastern Coalfields provide easy access to power grade coal. Delhi has plants which use coal, oil and gas but coal still remains the dominant fuel, Mumbai having easy access to natural gas has gas based plants, although the older units fire LSHS/Coal, also in relatively small quantities.

Table 5.27. Estimated oil consumption in Calcutta (kl)

	Mulajore	New Cossipore	Titagarh	Southern	Bandel	Kasba	Total
1988/89	2529.5	3951.8	11137.0	0.0	39048.2	0.0	56668.5
1991/92	2062.6	3847.4	15113.1	11527.3	19152.1	0.0	51702.5
1994/95	1240.7	2393.3	6834.6	2101.6	15553.4	116.8	28240.4
1997/98	1437.4	2770.6	7911.9	2432.8	18004.9	135.2	32692.8
2000/01	1634.4	3152.6	9002.9	2768.3	20487.7	153.8	37199.8
2001/02	1703.0	3285.0	9381.1	2884.6	21348.2	160.3	38762.2

Table 5.28 gives the emission factor for power plants. The resultant emission level of each pollutant is calculated using the emission factors and based on the generation and control technologies available in the plants. Figure 5.26 shows the level of emissions of TSP, NO_x and SO_2 in the three cities in 1994.

Table 5.28. Emission factors in power plant

Fuel	Unit	Pollutant				
		TSP	SO_2	NO_x	CO	HC
Coal	kg/tonne	8A pulverised coal	19.5 S	7.5	1	0.5
		6.5A stoker fired	19.5 S	7.5	1	0.5
Oil	kg/kl	1.25S+0.38	19.25 S	6.25 12.6 others	0.63	0.12
Gas	$g/10^3m^3$	48	15600 S	2240	272	16

Source Rapid Inventory Tecniques in Environmental Pollution, WHO, Geneva, 1993 URBAIR Report, NCR Report, TERI

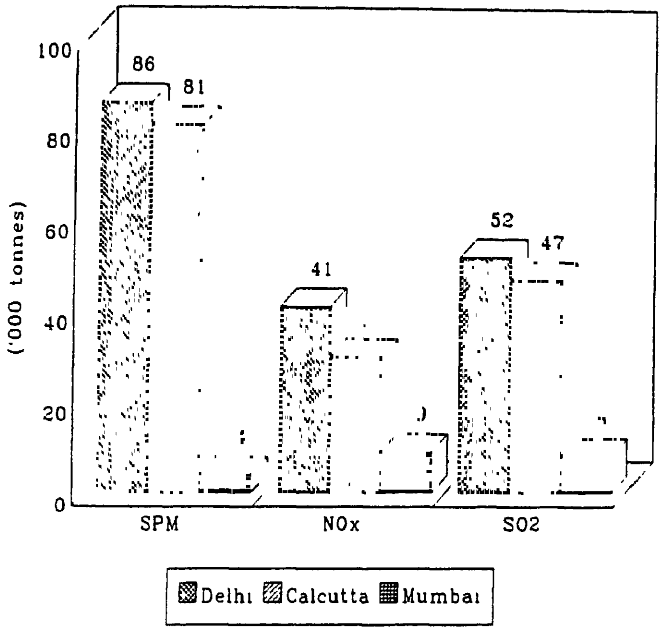


Figure 5.26. Comparative profile of TSP, NO_x and SO_2 (1994)

In both Delhi and Calcutta, it is seen that the main pollutant is TSP (which is however claimed to be within the prescribed limits). The NO_x and SO_2 emissions are becoming fairly significant and their emission loading by 2001/02 is of the same magnitude as that of TSP in 1988/89.

Figure 5.27. shows the emissions of all five pollutants in Delhi.

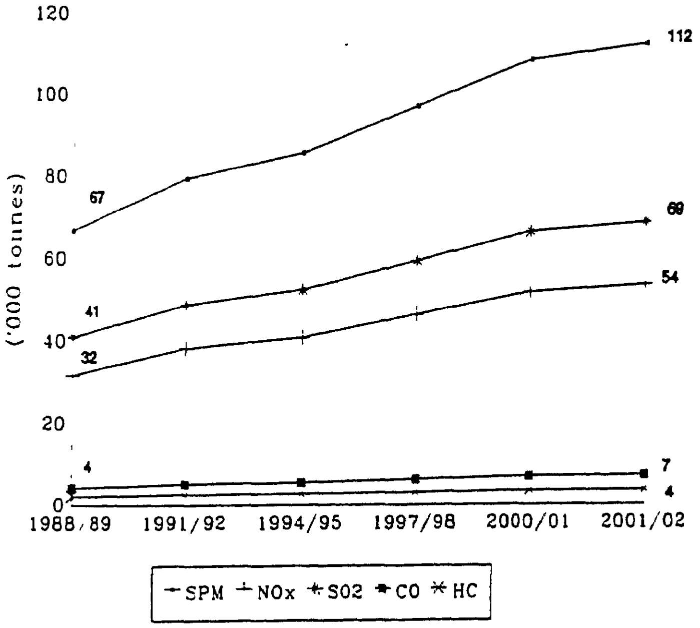


Figure 5.27. Base case emissions in Delhi

As shown in Figure 5.28, the TSP emissions in Calcutta reveal a sudden dip in 1997/98. This is due to the switching over of the Bandel power plant from the use of Multi cyclones (with 85% efficiency) to ESPs. Mulajore and New Cossipore use the stoker fired technology which results in larger quantity of bottom ash and only about 20% of the ash is emitted as fly ash. Therefore, even though the technology itself is more inefficient, this led to lower emissions of TSP. However, all the new units use the more efficient pulverized fuel technology. ESPs have been installed in all the units functioning as of date in order to contain the level of TSP emissions within the prescribed limits. As per the records, the ESPs are normally functioning at efficiency levels of as high as 99%. In the base case scenario, however we have assumed ESPs working at 95% efficiency levels to account for periods of maintenance and disfunctioning etc. The other pollutants (SO_2, NO_x, HC & CO) are uncontrolled and are seen to increase with higher generation levels over time.

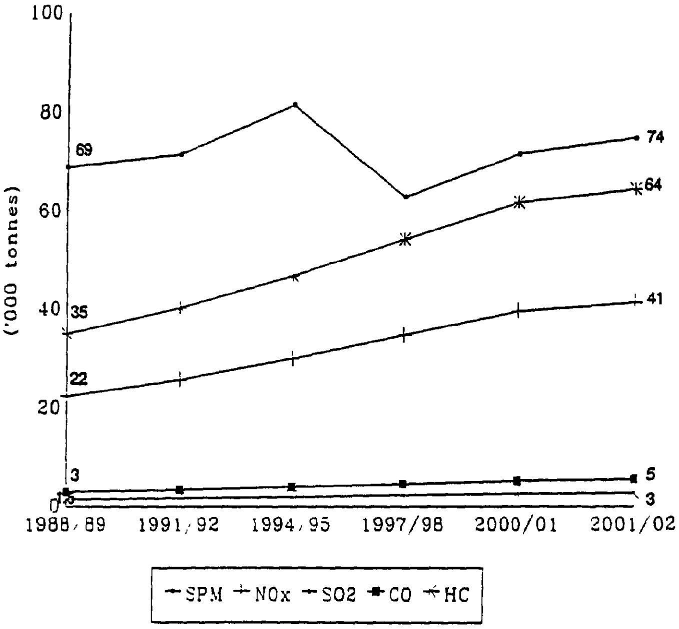


Figure 5.28. Base case emissions in Calcutta

An analysis of these emissions indicates that even with the installation of ESPs which function at 95% efficiency levels, the problem of emissions related with TSP is contained within limits. The growth in TSP emissions at this level has been at 5% per annum, but the problem from this pollutant is not so severe since the toxicity levels are much lower. The main concern stems from SO_2 emissions which been increasing from these power plants at around 4% per annum and which have a much higher toxicity level on a per tonne basis. At present, there are no standards for limiting the emissions of SO_2

and NO_x.

The city of Calcutta is located in Eastern India which has rich coalfields and large hydro reserves. Therefore majority of the power stations have coal based thermal plants. Before the environmental standards had come into force, the use of Multicyclones as a control technology for reduction of TSP emissions was fine. However, with the current standards, it has become necessary for all the units to install ESPs since Multicyclones are unable to capture the smaller particulates. Also, the older plants such as Mullajore and New Cossipore use the stoker fired technology rather than the pulverized fuel technology which is prevalent these days.

It is difficult to estimate the emissions from the TEC plant at Mumbai since disaggregated data on unitwise generation and specific fuel consumption levels was not available. However, an attempt has been made to work out the unitwise generation levels based on the average generation per day for the individual units and with information regarding closure/ usage patterns of the units. Table 5.29 gives the estimated fuel consumption in Mumbai by the TEC power plants.

Table 5.29. Estimated fuel consumption in Mumbai (TEC thermal)

	Coal	LSHS	Gas
	'000 tonnes	kl	mcm
1988/89	150	716642	422
1991/92	199	904821	532
1994/95	214	1025340	603
1997/98	273	1308781	770
2000/01	310	1484620	874
2001/02	323	1546592	910

The estimated emissions are provided, but these may be treated with caution. Since the new units at Trombay are generally run on gas/oil, the problem of TSP emissions is not much as revealed in Figure 5.29. SO_2 and NO_x emissions may be expected to pose a greater problem but the levels of these emissions are also much less compared to these emissions in either Delhi or Calcutta. For containing the emissions of Sulphur, TEC has been planning in advance and has already taken specific steps both towards increasing the stack heights of the new units and of having FGD units installed in Units 5 & 6.

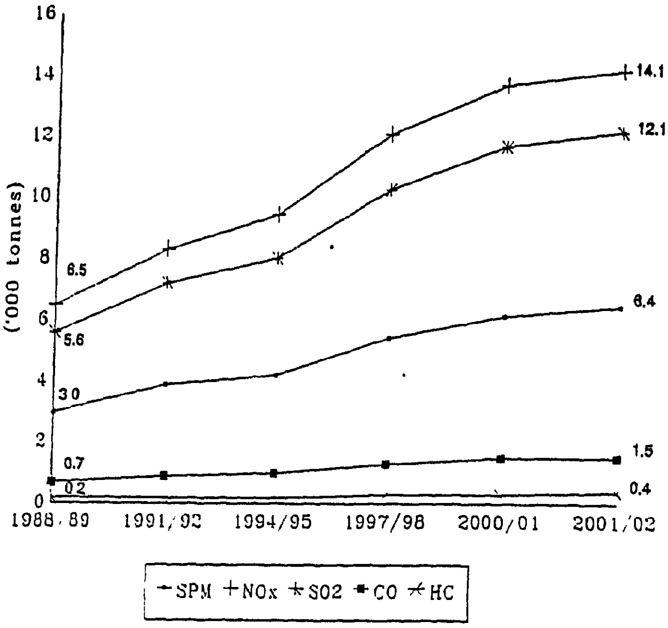


Figure 5.29. Base case emissions in Mumbai

The yearwise estimated emissions for the three cities is given in the Annexure 5.19, 5.20 & 5.21.

5.2.2. Alternative strategies

Even though cleaner and more efficient fuels are sought to be increasingly used in order to move towards more environmentally benign generation technologies, it is expected that coal and oil will continue to be the major fuels used for generating power. The use of gas is often inhibited by the lack of infrastructure for transporting gas to various locations, and renewable sources such as wind, small hydro and solar energy would only serve only a fraction of the future requirements for power. Since, the use of coal for power generation in India is likely to continue to increase over the next couple of decades, it would also continue to be a major source of air pollution unless adequate measures are taken to contain the emissions Therefore, it is important to examine various options by which power generation could be a more environmentally benign process.

Options for reducing emissions from power plants include efficiency improvement measures (which would lead to a lower utilization of fuels for generating the same amount of power) as well as the adoption of control technologies (at various stages of the power generation process). The following section provides a comparison of the base case emissions with 5 alternative scenarios for power generation in Delhi and Calcutta. These alternatives could even be used as retrofit technologies for the existing plants. Due to lack of adequate technological details, the scenario analysis has not been extended for the city of Mumbai. The air pollution as a result of power generation in Mumbai however does not hold as much concern since most of the capacity today is gas based and the Tata Electric Companies have installed 2 FGD units (for SO_2 control), increased stack heights of chimneys (for greater dispersion of the pollutants emitted) and upgraded control equipment for TSP control (ESP installations and enhancements).

For future power generation capacity, it is expected that advanced generation technologies such as AFBC, PFBC and IGCC would become popular, and these are briefly discussed as future options for India.

5.2.2.1. Scenario 1: Better housekeeping and operating practices

This alternative scenario considers the adoption of better housekeeping and operating practices in power plants at no additional investment cost. It is estimated that such measures can easily result in a 10% increase in efficiency of the power plants (or reduce the specific fuel consumption levels by 10%). Efficiency improvements due to better housekeeping are introduced in all the plants in the 2 cities after 1997/98. Figure 5.30 indicates the resultant reduction levels as compared to the base case scenario.

This scenario presents a "win-win situation" since it does not involve any additional cost and could lead to reduction in the use of fuels and therefore impact of the resultant pollutants on the health of the people residing in these cities. It is therefore recommended that all power plants should at least resort to simple housekeeping measures as a first step towards achieving a better environment. Enhanced efficiency would in fact lead to additional benefits in terms of cost of fuel saved by the utility.

5.2.2.2. Scenario 2: Improved performance of control technologies

Over the past couple of decades, most of the coal based power plants have installed some kind of control device as an end-of-pipe measure to contain air pollution. ESPs in most of the plants are reported to work at 99% efficiency levels while multicyclones are reported to be 90% efficient. However, it is generally felt that these devices do not always work at these efficiency levels and there are often periods where the devices do not function properly due to poor maintenance.

Under the base case, it is assumed that the average efficiency of ESPs is 95% and that of Multi cyclones is 85%. In the alternative scenario, the ESPs are assumed to achieve the reported levels of 99% efficiency and Multi cyclones to achieve 90% efficiency levels.

The comparative emission levels under this scenario and the base case are also presented in the Figure 5.30 for the 2 cities. It is seen that the TSP levels in both the cities are seen to decrease drastically - from 112 to 23 thousand tonne in Delhi and from 74 to

31 thousand tonne in Calcutta in 2001/02. This is another fairly simple procedure which power plants could easily resort to at fairly low costs.

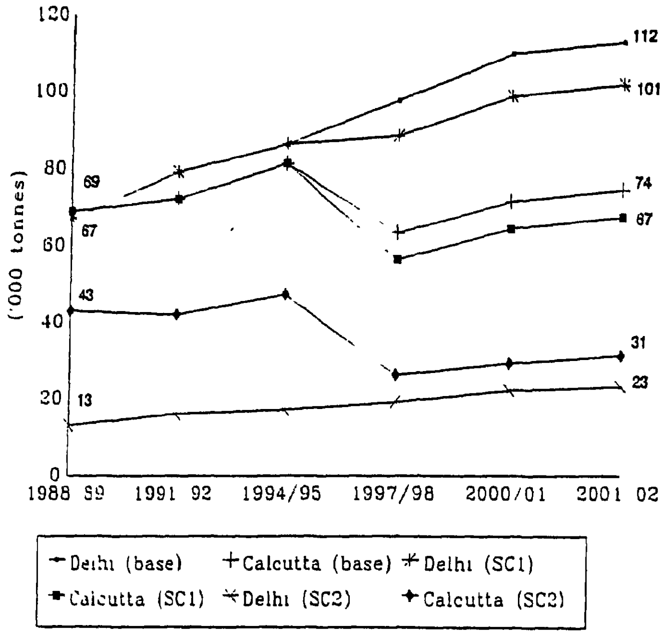


Figure 5.30. Alternative scenarios for reduction in TSP

In the base case projections, it is observed that the emissions of both SO_2 and NO_x are rapidly increasing and in the absence of any standards for these pollutants, these are expected to continue unabated. The levels (in tonnes) of SO_2 and NO_x in Delhi and Calcutta in 2001/02 are seen to be nearing the 1988/89 TSP emissions in these cities. In terms of toxicity levels of the various pollutants, NO_x and SO_2 have relative weights of 4.7 and 1.4 as compared to 1.26 for TSP (assuming 55% of TSP is PM_{10}) (*Air Quality Management. Considerations for Developing Countries, World Bank, 1995*). Therefore, the toxic effects due to SO_2 and NO_x are expected to be worse than by TSP, since efforts are being directed at containing TSP emissions by power plants. Against this background, scenarios 3 and 4 have been developed to examine the potential for reducing emissions of NO_x and SO_2 from power plants in the 2 cities. Scenarios 3 and 4 are discussed in the next two sections.

5.2.2.3. Scenario 3: Adoption of low-NO_x combustion technologies

Inclusion of low-NO_x burners in new boilers has been considered as an alternative option since the incremental costs in this case are minimal. The option either includes overfire air systems or make provisions in boiler design for easy incorporation of overfire air in the future. Even though minor adaptations may be required to accommodate the unique characteristics of some coals (especially in countries such as China and India), no full-scope technology demonstration project is needed. Most developing countries have the capability (manufacturing facilities) to acquire the technology and to manufacture low-NO_x systems locally, although transfer of technology know-how may be required.

Low-NO_x burners (LNBs) are designed to "stage" combustion. In this technology, a fuel-rich combustion zone is created by forcing additional air to the outside of the firing zone (auxiliary air) and by delaying the combustion of coal. Reduction of 30 to 55 percent of NO_x can be achieved with low-NO_x burners. The alternative scenario has considered the possibility of a 30% reduction after 1997/98.

A comparison of the base case NO_x emissions with those in the scenario 3 for Delhi and Calcutta is shown in Figure 5.31. The costs of retrofitting existing boilers with low-NO_x burners are estimated to range from US$ 5/kW to US$ 50/kW. Lack of environmental regulations requiring NO_x emission control however, seems to be the major reason for the limited use of these technologies in developing countries. It is seen that NO_x emission levels in 2001/02 can be maintained near 1988/89 levels with adoption of the low NO_x technologies in the 2 cities.

5.2.2.4. Scenario 4: Adoption of sorbent injection technology for SO_2 control

This technology involves the removal of SO_2 by injecting a Sorbent (lime, limestone, or dolomite) into the combustion gases. The sorbent decomposes into lime, which reacts in suspension with SO_2 to form calcium sulfate ($CaSO_4$). The calcium sulfate, unreactedsorbent, and fly ash are removed at the particulate control device (either an

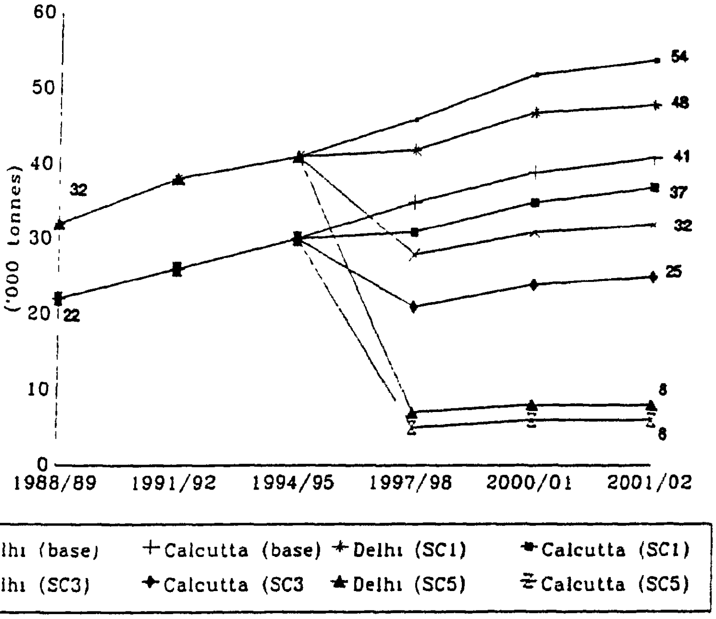


Figure 5.31. Alternative scenarios for NO_x reduction

electrostatic precipitator or bagfilter downstream from the boiler. Sorbent injection, however, affects the properties of the particulates which in turn adversely affects the performance of ESP so that gas conditioning may be needed to maintain the ESP's performance.

SO_2 removal by this technology is generally 30 to 60 percent. In the alternative scenario considered, a 45% SO_2 removal is considered after 1997/98. The technology is suitable for both new and retrofit applications though a number of issues must be addressed before the technology is considered fully demonstrated and commercially available. It is more advantageous than other technologies since it requires very little space, uses readily available additives (sorbent), and is easy to operate and maintain. Capital costs of this technology range between 70 to 120 US$/kW.

Figure 5.32 gives a comparison of SO_2 emissions in the base case vis-a-vis the reduction scenario. With the control technology, the emissions in 2001/02 are maintained at 1988/89 levels. In light of the toxicity levels associated with this pollutant, it may be advisable to invest in control technologies at an early stage especially in cities where large populations may be exposed to these emissions.

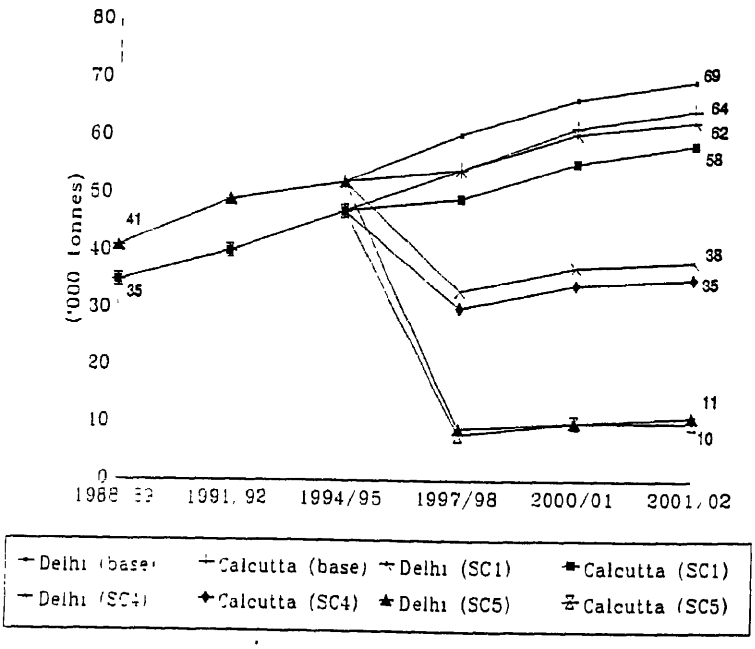


Figure 5.32. Alternative scenarios for SO_2 reduction

5.2.2.5. Scenario 5: Combined SO_2/NO_x control

Combined SO_2/NO_x control processes include absorption/regeneration, flue-gas irradiation, wet scrubbing with additive for NO_x removal, gas/solid catalytic operations, electrochemical processes, and dry alkali processes. A NO_x removal of 80 to 90 percent and a similar level of SO_2 removal are expected from these processes. The alternative scenario considers a reduction of 85% both in case of SO_2 & NO_x after 1997/98. It is however likely that such processes would not be adopted in India unless there are stringent standards for reduction in emissions of SO_2 & NO_x. The cost would also be another major deterrent towards opting for this technology.

5.2.2.6. Scenario 6: Coal washing for TSP reduction

This scenario considers the option of washing coal for reducing its ash content and consequently its TSP emissions. Recently a gazette has been passed wherein all coal for power plant should have a maximum of 34% ash content. This standardization of ash content would serve a dual purpose - firstly, to reduce the direct emission of particulate matter and secondly, to improve the efficiency of power plants themselves. Since coal being used in Calcutta already has an ash content of 25%, this scenario has been considered only for the city of Delhi. It has been assumed that the ash content would diminish to 34% from the existing 40% after 1997/98. This would also simultaneously lead to a specific fuel consumption of approximately 0.60 from 1997/98 onwards as compared to more than 0.8 prior to this period. The cost for coal washing is estimated to range between Rs. 150 to 200 per tonne of coal washed. Figure 5.33 shows the comparative emissions of TSP in the base case and under the coal washing scenario for the city of Delhi.

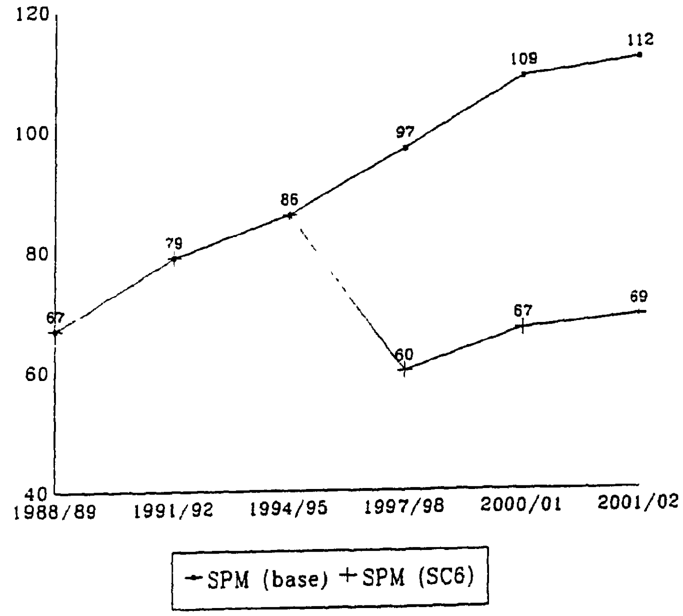


Figure 5.33. Reduction in TSP in Delhi with washing of coal

It is seen that TSP levels under scenario 6 (SC6) have decreased by 38% from the base case in the year 2001/02.

5.2.3. Introduction of cleaner coal based technologies

Apart from the six scenarios considered above, future capacity additions should consider advanced coal utilization technologies such as AFBC and PFBC which are both ready for use in developing countries, as well as technologies still in high cost or demonstration phases, such as IGCC. These technologies are briefly discussed below.

5.2.3.1. Atmospheric fluidized-bed combustion

AFBC technologies are adaptable to both new and existing installations, work well in combination with other technologies, and are suitable for many local coals. However, their acceptance in many developing countries has been slowed by a lack of regulations requiring high removal of SO_2.

AFBC boilers can remove up to 90 to 95 percent SO_2, while generating 100 to 300 ppm NO_x emissions. Bubbling AFBC usually removes 70 to 90 percent of the SO_2 depending on the coal's characteristics and the amount of limestone added. Circulating AFBC can achieve 95 percent SO_2 removal, with a calcium-to-sulfur (Ca/S) molar ratio of 1.5 to 2.0. NO_x emissions can be reduced further (to 10 ppm) with the addition of selective noncatalytic reduction (SNCR) processes. Boiler and overall plant efficiency of both AFBC types are similar to those of conventional pulverized-coal plants (*E.S. Tavoulareas, WB, 1995*).

AFBC boilers are capable of burning low-quality coals (e.g., low-heating-value lignites, coal cleaning wastes, petroleum coke, and other waste materials). Also, the same boiler can accommodate a wider range of fuels than conventional pulverized-coal boilers. The estimated capital costs for a 150 to 200 MW AFBC range from US$1300 to 1600/kW (*E.S. Tavoulareas, WB 1995*). Therefore, the AFBC technology should be chosen when fuel flexibility is desirable, low-quality fuels are available, low-NO_x emissions are required, and high (70 to 90 percent) SO_2 removal is desired.

AFBC technology is particularly adaptable for developing countries because it can burn the local coals (especially in China, India, Pakistan, and Eastern Europe). In addition, AFBC is similar in design, manufacturing, and operation to pulverized-coal technology. Thus, it can be introduced and used by developing countries with minimal transition and effort.

Although circulating AFBC is the preferred option in developed countries, developing countries may also choose bubbling AFBC technology, which provides adequate SO_2 removal (70 to 90 percent), is less expensive, and is simpler to operate. The main barrier keeping AFBC from wide application in developing countries is the lack of high SO_2 removal requirements. In developing countries, AFBC has to compete against conventional pulverized-coal plants, which have no SO_2 control technology. As SO_2 removal requirements increase to 60 to 90 percent, more and more AFBC boilers are likely to be used in developing countries in India.

5.2.3.2. Pressurized fluidized-bed combustion technology

PFBC technology uses a combustion process similar to that of AFBC, but the boiler operates at higher than atmospheric pressure (5 to 20 bar), the gas is cleaned downstream from the PFBC boiler, and the gas is expanded in a gas turbine.

PFBC has the advantages of AFBC technology (high SO_2 removal, low-NO_x emissions, ability to burn low-quality fuels, and fuel flexibility) in addition to having a compact design as well as potential for achieving higher plant efficiency (up to 45 percent) than conventional pulverized coal or AFBC (36.5 percent).

PFBC technology can achieve more than 90 percent SO_2 removal, with Ca/S molar ratio of 1.5 to 3.0; can control NO_x emissions at 100 to 200 ppm or less; and achieve 40 to 42 percent efficiency in a combined cycle arrangement.

Projections of capital costs for PFBC range from US$1200 to 1550/kW (*E.S. Tavoulareas, WB, 1995*). At present, this technology is suitable for most coals available in developing countries, but technology demonstration may be required. Local manufacturing may not be feasible for the key components (boiler pressure vessel, hot-gas cleanup system, and gas turbine) because of the need for specialized equipment and highly trained personnel.

5.2.3.3. Integrated gasification combined-cycle

Coal gasification is a process that converts solid coal into a synthetic gas composed mainly of carbon monoxide and hydrogen. Coal can be gasified in various ways by properly controlling the mix of coal, oxygen, and steam within the gasifier. There are also several options for controlling the flow of coal in the gasification section (e.g., fixed-bed, fluidized-bed, and entrained-flow systems).

Because of its high cost and early stage of development, IGCC technology is, for the near future, an unlikely choice of technology for developing countries with lenient SO_2 removal and NO_x emission regulations. However, it is one of the few technologies (the other being PFBC) that significantly increases power plant efficiency and will have a beneficial effect in reducing emissions of CO_2. As such, IGCC, like PFBC, is a technology that may be used in developing countries like India in the long term.

IGCC, like PFBC, combines both steam and gas turbines ("combined cycle").

Depending on the level of integration of the various processes, IGCC may achieve 40 to 42 percent efficiency.

The fuel gas leaving the gasifier must be cleaned (to very high levels of removal efficiencies) of sulfur compounds and particulates. Cleanup occurs after the gas has been cooled, which reduces overall plant efficiency and increases capital costs, or under high pressure and temperature (hot-gas cleanup), which has higher efficiency. However, hot-gas cleanup technologies are still in the early demonstration stage.

After the fuel gas has been cleaned, it is burned and expands in a gas turbine. Steam is generated and superheated in both the gasifier and the heat recovery unit downstream from the gas turbine. The fuel gas is then directed through a steam turbine to produce electricity.

IGCC plants can achieve up to 45 percent efficiency, greater than 99 percent SO_2 removal, and NO_x below 50 ppm.

IGCC cost projections range from US$1500 to 1800/kW; 10 to 20 percent higher than for pulverized-coal with wet scrubbers (*E.S. Tavoulareas, IFB, 1995*). IGCC technology may be the technology of choice when high SO_2 removal (e.g., 99 percent or higher) and low-NO_x emissions (below 100 ppm) are required.

The primary constraints towards the adoption of the technology at this juncture are that the technology needs further demonstration, the costs are higher than those of competing technologies, and the fact that environmental regulations in developing countries do not require the high SO_2 removal and low-NO_x emissions achieved by IGCC. However, high-ash coals, such as those in India, would require fluidized-bed gasification processes

5.3. Industrial sector

5.3.1. Energy intensitv and emissions in Delhi

Table 5.30 gives the growth of energy intensive manufacturing industries during the years 1989/90 and 1993/94 in the four cities. Since no uniform information is available at city level, available data from ASI for the respective states is studied to analyse the trends in industrial development.

From Table 5.30, it is observed that most of the energy intensive industries have grown considerably between 1989/90 and 1993/94. In West Bengal there has been significant growth in industries 23 (37%), 24 (44%) and 32 (39%) while there has been a marginal decline in industries 28 (2.24%), 30 (2.27%) and 31 (1.1%). In Maharashtra, there has been a marginal growth in almost all the industries (ranging between 3.24% and 40.32%) except 24 (manufacture of wool, silk and fibre textiles) which has declined marginally (7.54%). In Karnataka there has been a significant decline in industry 24 (41%)

and a marginal decline in 23 (5.47%), 28 (5.9%) and 33 (13.31%) while there has been a marginal growth in the rest of the industries (ranging between 1.14% and 25%). Figures 5.34, 5.35, 5.36 and 5.37 summarize the growth trends (represented in percentage change) in the energy intensive industries in Delhi, West Bengal, Maharashtra and Karnataka respectively in 1989/90 and 1993/94.

The following section analyzes the variables influencing changes in energy intensities and emission during 1989/90 and 1993/94 for the following selected energy intensive manufacturing industries in Delhi. These include 20-21: food products; 23: cotton textiles; 24: wool, silk and man-made fibre textiles; 28: paper and paper products and printing, publishing and allied industries; 30: basic chemicals and chemical products (except products of petroleum and coal); 31: rubber, plastic, petroleum and coal products, processing of nuclear fuels; 32: non-metallic mineral products; and 33: basic metal and alloys industries.

5.3.1.1. Manufacture of food products

The manufacture of food products (NIC code 20-21) is one of the important industry in Delhi with over 142 industries in operation. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows;

Industry Code	Type of industry
2010	Manufacturing of dairy products
2020	Canning and preservation of fruits and vegetables
2041	Flour milling by power machine
2049	Other grain milling and processing activities
2050	Manufacturing of bakery products
2111	Manufacturing of vegetable oils and fats
2160	Manufacturing of ice
2199	Other food processing

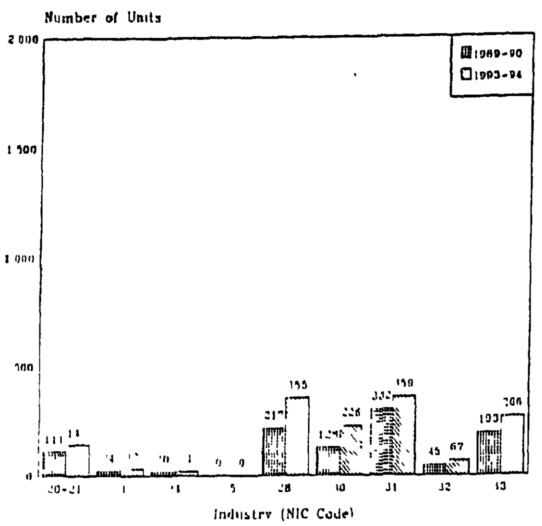


Figure 5.34. Growth of industries in Delhi
1989/90 & 1993/94

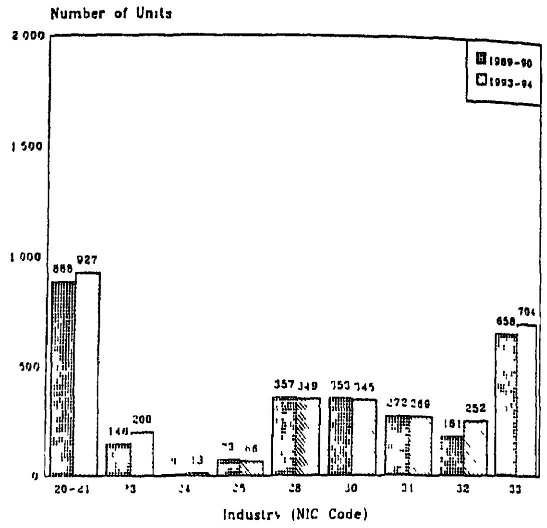


Figure 5.35. Growth of industries in West Bengal
1989/90 & 1993/94

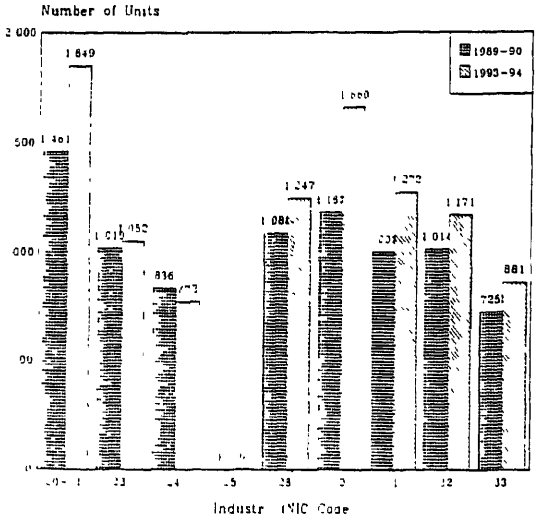


Figure 5.36. Growth of industries in Maharashtra
1989/90 & 1993/94

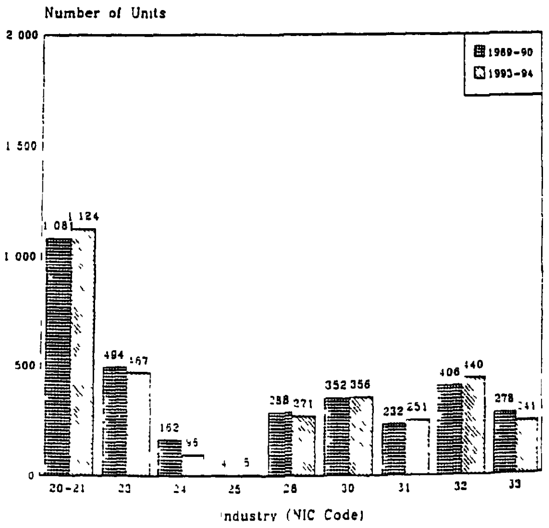


Figure 5.37. Growth of industries in Karnataka
1989/90 & 1993/94

Table 5.30. Growth of energy intensive industries (as per ASI data) in the states of Delhi, West Bengal, Maharashtra and Karnataka during 1989/90 and 1993/94

Industry (NIC Code)	Type of industry	Delhi			West Bengal			Maharashtra			Karnataka		
		1989/90	1993/94	% Growth	1989/90	1993/94	% Growth	1989/90	1993/94	% Growth	1989/90	1993/94	% Growth
20 21	Manufacturing of food products	111	142	27 93	888	927	4 39	1461	1849	26 56	1081	1124	3.98
23	Manufacture of cotton textiles	24	32	33 33	146	200	36 99	1019	1052	3 24	494	467	-5.47
24	Manufacture of wool, silk and man-made fibre textiles	20	21	5 00	9	13	44 44	836	773	-7 54	162	96	-40 74
28	Manufacture of paper and paper products and printing, publish	217	355	63 59	357	349	-2 24	1088	1247	14 61	288	271	-5 90
30	Manufacture of basic chemicals and chemical products	128	226	76 56	353	345	-2 27	1183	1660	40 32	352	356	1.14
31	Manufacture of rubber, plastic, petroleum and coal products	302	359	18 87	272	269	-1 10	1002	1272	26 95	232	251	8.19
32	Manufacture of non-metallic mineral products	45	67	48 89	181	252	39 23	1014	1171	15 48	406	440	8.37
33	Basic metal and alloys industries	193	266	37 82	658	704	6 99	725	861	18 76	278	241	-13.31

Source GOI, Annual Survey of Industries Summary of Results for Factory Sector, 1989/90, Calcutta, Central Statistical Organisation, GOI, Annual Survey of Industries Summary of Results for Factory Sector, 1993/94, Calcutta, Central Statistical Organisation.

While analysing the data, the following four digit level industries were not included viz., 2041 and 2049 has not been considered due to unacceptable variations in the energy consumption and negative value addition respectively.

The net value added (NVA) has increased over two times in this sector with a NVA of 430.6 million rupees in 1993/94, at constant (1980/81=100) prices is given in Table 5.31. The total energy consumption has reduced marginally (by 5.94%) between 1989/90 and 1993/94. This indicates some structural changes particularly in the form of shift to higher value added products in the sector. This is evident from the large increase in NVA in industry 2010 and industry 2111 where the increase is of the order 393% and 784% respectively which are the two major contributors to the value addition in this sector with the shares of 18.8% and 58% respectively.

Table 5.31. Energy intensity, value addition, input cost and gross value of plant and machinery for sector 20-21 (food products, sugar & breweries) in Delhi for the year 1989/90 and 1993/94.

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2010	Manufacturing of dairy products	5999	5814	16368	80774	1088005	1072868	34302	6346	0.3665	0.0720	0.015	0.075
2020	Canning and preservation of fruits and vegetables	1424	446	60719	8435	62377	56623	15237	3739	0.0235	0.0529	0.973	0.149
2050	Manufacturing of bakery products	3655	4312	65082	61156	255879	416538	36020	45302	0.0562	0 0705	0.254	0.147
2111	Manufacturing of vegetable oils and fats	1121	998	28263	249871	232163	129612	6108	5407	0.0396	0.0040	0.122	1.928
2160	Manufacturing of ice	482	388	1159	1861	5684	6236	4422	2249	0.4157	0.2082	0.204	0.299
2199	Other food processing	1695	1563	24861	28574	90778	123842	27160	16265	0.0682	0.0547	0.274	0.231
20-21	Total	14375	13521	196451	430672	1734887	1805718	123250	79309	0.0732	0.0314	0.113	0.239

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year.

The large increases in NVA and NVA/input cost ratio (which has gone up by about 112% with the ratio at 0.239 in 1993/94) is mainly due to the structural changes that have taken place in the sector whereas the gross value of plant and machinery has gone down (by 35.65% with a value of Rs. 79.3 million in 1993/94 at constant prices) during the same period. This also signifies the improvements that have taken place in energy efficiency through technological interventions. This is evident from the large decline in energy intensity (57.1%) in this sector (from 0.0732 toe/thousand rupees to 0.0314 toe/thousand rupees) which is largely reflected through the reduction in energy intensities in major contributors to value addition in this sector viz. The decline in energy intensity in industry 2010 is of the order 80.4% and in industry 2111 is of the order 89.9% Figure 5.38. However, the major increase (almost doubled) in the energy intensity of industry 2020 with a value of 0.0529 toe/thousand rupees in 1993/94 and the little increase case of industry 2050 with a value of 0.0705 in 1993/94 are not very significant since their contribution to NVA is very nominal.

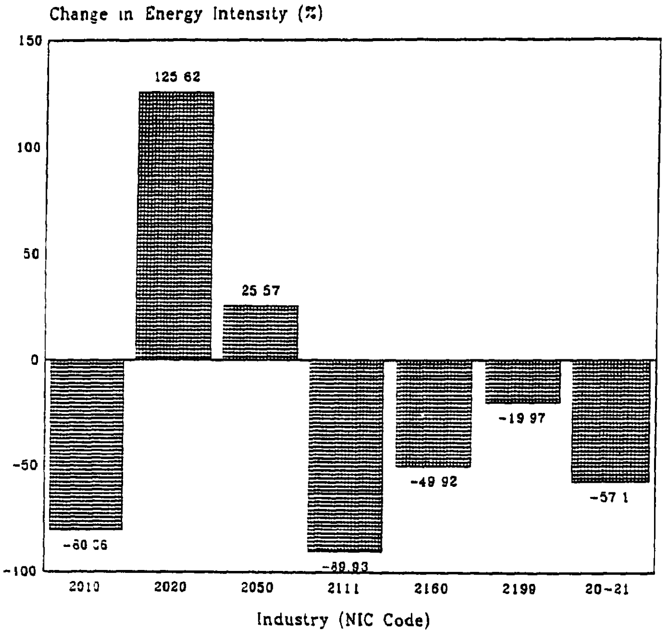


Figure 5.38. Changes in energy intensity of industry 20-21 during 1989/90 & 1993/94

While the total energy consumption has marginally declined by 6.32% from 1989/90 (13521 toe in 1993/94) the energy mix has undergone a marginal change Table 5.32. There was a slight decline in coal share from 19.46% to 14.32%, a small increase in the consumption of electricity purchased which has increased from 29.72% to 32.08%, a marginal increase in oil consumption from 49.71% to 51.85%. When analysed the details of consumption trends within the sector, it was observed that the shift from coal usage to oil has taken place mainly in case of the NIC 4 digit level industries 2111 where there was a 21.3% decrease in the share of coal usage and 19.7% increase in the share of oil usage, and 2199 where there was 12.5% decrease in the share of coal usage and 6.2% increase in the share of oil usage along with a 7.7% increase in the share of natural gas. There is also a small fraction of shift from oil to electricity in case of 2020-canning and preservation of fruits and vegetables and 2050 (about 4.7% decrease in the share of oil usage and 4.8% increase in the share of electricity purchased). This change is a result of changes to higher value adding products. Further, the shift of fuel use from coal to natural gas, oil and electricity purchased is considered healthy from the point of view of environmental pollution since the emissions from usage of these energy modes is much less in comparison to the coal usage.

The outcome of the analysis of the energy consumption in this industry is that, in view of the increasing trend in the net value added, and the decreasing trend in energy intensity coupled with the improvements in energy efficiencies resulting in stabilising the energy consumption levels with higher value additions are healthy indicators for improved environmental performance of the industries in this sector.

Emissions from this sector have also been estimated using appropriate emission factors. It was found that the TSP from coal combustion is the main pollutant emitted from these industries besides SO_2, NO_x and CO from both coal and oil combustion. Annual emissions of TSP were found to be of the order 1067 tonnes, SO_2 were of the order 323 tonnes, NO_x 385 tonnes and CO 36 tonnes in 1993/94 Table 5.33. Between 1989/90 and 1993/94, the TSP emissions have come down by 28%, SO_2, NO_x and CO emissions have increased by 285%, 317%, and 256% respectively. The changes in the fuel mix during this period, especially the shift of fuel use from coal to oil and electricity could be attributed to the reduced TSP and increased emission of the remaining pollutants. This trend is certainly seen as positive and good from the point of view of the reduced contribution of pollution emissions to the city's atmosphere and improving environmental performance of the industry.

Table 5.32. Total energy consumption and percentage shares of various fuels in sector 20-21 (food products, sugar and breweries) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2010	Manufacturing of dairy products	778 (12 97)	1087 (18 70)	24 (0 40)	0 (0)	2781 (46.36)	2359 (40.57)	2416 (40.27)	2368 (40.73)
2020	Canning and preservation of fruits and vegetables	1060 (74 42)	356 (79 80)	0 (0)	9 (2 05)	312 (21 87)	52 (11.56)	53 (3.71)	29 (6.59)
2050	Manufacturing of bakery products	39 (1 07)	64 (1 49)	21 (0.56)	0 (0)	3052 (83.52)	3401 (78.86)	543 (14.85)	847 (19.65)
2111	Manufacturing of vegetable oils and fats	694 (61 92)	406 (40 67)	0 (0)	0 (0)	196 (17.48)	371 (37.20)	231 (20.60)	221 (22.13)
2160	Manufacturing of ice	0 (0)	9 (2 40)	0 (0)	0 (0)	46 (9 59)	32 (8.29)	436 (90.41)	346 (89.31)
2199	Other food processing	226 (13 36)	13 (0 82)	115 (6 8)	227 (14.53)	159 (44 77)	797 (50.98)	594 (35.07)	526 (33.67)
20-21	Total	2797 (19.46)	1936 (14.32)	160 (1.11)	236 (1 75)	7145 (49.71)	7011 (51.85)	4272 (29.72)	.4338 (32.08)

Note. Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.33. Fuel-wise contribution of emissions from industry 20-21 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	1484	1027	0.01	0.01	6	40	1490	1067
SO_2	43	30	0	0	40	293	84	323
CO	6	4	0.05	0.07	4	32	10	36
HC	3	2	0.01	0.01	1	7	4	9
NO_x	43	30	0.42	0.62	49	355	92	385

5.3.1.2. Basic chemicals and chemical products (except products of petroleum and coal)

Manufacture of basic chemicals and chemical products (NIC code 30) is one of the major industry in Delhi with over 226 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows;

Industry Code	Type of industry
3002	Manufacturing of industrial gases
3014	Manufacturing of pesticides
3024	Manufacturing of natural polymers & modified natural polymers in primary forms
3032	Manufacturing of paints, varnishes, enamels, etc.
3035	Manufacturing of printing, writing, drawing ink
3042	Manufacturing of allopathic pharmaceutical preparations
3043	Manufacturing of 'aurvedic' of 'unani' pharmaceutical preparations
3051	Manufacturing of toilet soaps
3059	Manufacturing of others (incl. scented sachets, etc)

During 1989/90 and 1993/94, there is little decline in the net value added in this sector (19.79%) with a NVA of Rs.342/- million in 1993/94 at constant prices Table 5.34 while the total energy consumption has increased by 4.89% between 1989/90 and 1993/94. There was a major decline in NVA in 3032 (4697%) and a major decrease is observed in NIC 4 digit level industries 3002 (75.3%), 3014 (31.5%) and 3035 (43%), while the energy consumption levels have marginally increased in these industries except in 3002, 3014 and 3032. The mega contributor to NVA in 1989/90 was 3032 which has drastically fallen down to the least contributor in 1993/94, while other major contributors of NVA at present continue to be 3014 (18.2%), 3024 (25.5%), 3042 (16.6%) and 3051 (15.91%). This indicates that while there have been no major changes in the industry, the fall of NVA could probably be attributed to market trends which might have forced decline in production levels of this sector, particularly the industry 3032.

The decrease in NVA coupled with the slight increase in NVA/input cost ratio (which has gone up vary marginally from 0.190 to 0.194 in 1993/94), mainly leads to the conclusion that the production levels have gone down between the two years under study. Profitability in the industry (in India) was on a gradually declining trend between 1989/90 and 1993/94 (*CMIE, January 1996*). While the energy intensity in this sector has increased by about 31% (from 0.103 to 0.135 toe/thousand rupees), the plant and machinery cost has almost remained the same with a very little increase of 3% (which is of the order Rs 105 million in 1993/94). However, the energy intensities have changed considerably within the sector in the 4 digit level industries. The energy intensity has gone up considerably in industry 3032, by 1294%, (from 0.0011 in 1989/90 to 0.0155 toe/Rs.000 in 1993/94). While major increases in energy intensity have been observed in 3002 (161.4%), 3035 (114.5%), 3042 (93.2%) and 3059 (34.2%), decreases in energy intensities also have been observed in 3024 (74.7%), 3043 (92%) and 3051 (45.2%) Figure 5.39.The plant and machinery costs in this sector have also not changed much, though there has been some noticeable increase in some cases like industries 3014 (417.2%), 3032 (59%), the decline in others have kept the overall plant and machinery costs almost at the same levels.

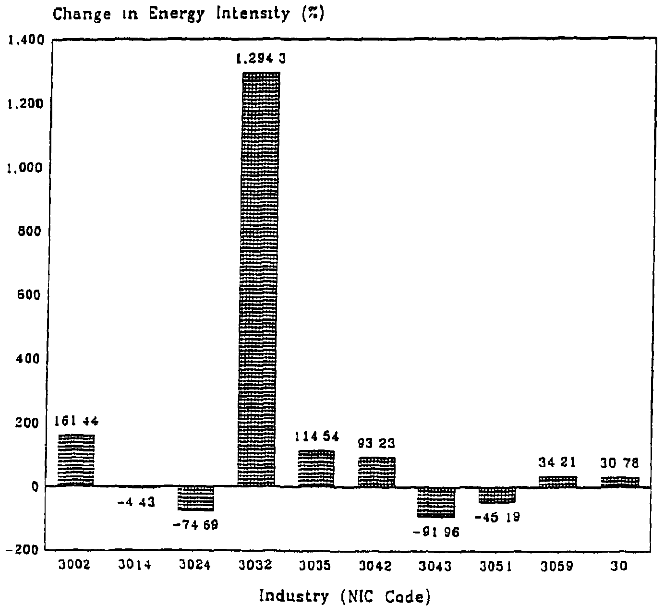


Figure 5.39. Changes in energy intensity of industry 30 during 1989/90 and 1993/94

While there has been a small increase (4.89%) in the total energy consumption (from 4405 toe in 1989/90 to 4620 toe in 1993/94), the energy mix has slightly changed with a move from coal and electricity purchased to oil. Between 1989/90 and 1993/94, the share of coal has come down from 9.66% to 5.92%, the share of electricity has come down from 37.33 to 30.86% while the share of oil has increased from 52.46% to 61.54%

and a very slight increase in the share of natural gas (from 0.56% to 1.68%). The details of fuel shares in 4 digit level industries also imply the above trends clearly which is evident from Table 5.35 the following; there is a major decline in coal consumption (by 55.6%) from 424 toe to 237 toe in industry 3051 in which the oil share and electricity shares have gone up from 21.95 and 6.27 to 38.81 and 16.53 respectively; there is a considerable increase in the share of oil from 56.47% to 75.31% in industry 3042 while the share of electricity purchased has at the same time come down from 40.73% to 23.70%. Similar trends have been observed in industries 3002 and 3024 (in 3002 the oil share has increased from 17.16% to 34.54% while the electricity share has decreased from 82.84% to 65.46% and in 3024 the oil share has increased from 68.81% to 78.65% while the electricity share has decreased from 31.19% to 21.35%). These changes in energy mix have probably resulted from the interventions made for energy efficiency improvements which is evident from the fact that the energy intensities in these particular industries, with shift from coal to oil or electricity to oil, have decreased.

The major observation from the analysis of energy consumption trends in this sector is that, the increasing trend in energy intensity (in general) and decreasing trend in the net value added coupled with the increasing trend in the overall energy consumption are leading to the indication that the environmental performance of the industries in this sector is not improving and is of some concern.

The emissions from this sector have been estimated using appropriate emission factors and it was found that the TSP from coal combustion is the main pollutant emitted from these industries besides SO_2, NO_x and CO from both coal and oil combustion. Annual emissions of TSP were found to be of the order 161 tonnes, SO_2 were of the order 117 tonnes, NO_x 141 tonnes and CO 13 tonnes in 1993/94 Table 5.36. Between 1989/90 and 1993/94, the TSP emissions have come down by about 30%, while SO_2, NO_x and CO emissions have increased considerably by 408%, 432%, and 385% respectively. The changes in the fuel mix during this period, especially the shift of fuel use from coal to oil and electricity coupled with energy conservation efforts could be attributed to the reduced TSP, and the increased emissions of the remaining pollutants could be partly attributed to the increased number of industries in this sector in Delhi. However, the high increase in overall emissions from the various industries in this sector and the associated implications on the pollution levels in the city can not be ignored in the interest of protecting the public health and environmental improvement in the city.

Table 5.34. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 30 (manufacture of basic chemicals and chemical products) in Delhi for the year 1989/90 and 1993/94

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3002	Mfg of industrial gases	591	381	12112	3070	73852	12201	27749	4445	0.0478	0.1249	0.168	0.252
3014	Mfg of pesticides	1203	788	90627	62075	181922	313409	4321	22347	0.0133	0.0127	0.498	0.198
3024	Mfg of natural polymers & modified natural polymers in primary forms	585	625	20622	87106	349542	164321	6791	3748	0.0284	0.0072	0.059	0.530
3032	Mfg. of paints, varnishes, enamels, etc	207	60	186204	3882	796106	36493	8638	13727	0.0011	0.0155	0.234	0.106
3035	Mfg. of printing, writing, drawing ink	119	146	13934	7949	89055	54679	1636	3970	0.0086	0.0184	0.156	0.145
3042	Mfg. of allopathic pharmaceutical preparations	632	1155	60006	56785	415706	456218	42603	35599	0.0105	0.0203	0.144	0.124
3043	Mfg. of 'aurvedic' of 'unani' pharmaceutical preparations	384	596	2457	47495	98646	132494	4562	6486	0.1563	0.0126	0.025	0.358
3051	Mfg of toilet soaps	590	530	33238	54419	19941	403269	3898	6638	0.0178	0.0097	0.167	0.135
3059	Mfg. of others (incl scented sachets, etc)	90	336	6875	19218	43756	188640	2130	8591	0.0130	0.0175	0.157	0.102
30	Total	4405	4620	426394	341998	2248079	1761724	102329	105551	0.0103	0.0135	0.190	0.194

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.35. Total energy consumption and percentage shares of various fuels in sector 30 (manufacture of basic chemicals and chemical products) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3002	Manufacturing of industrial gases	0 (0)	0 (0)	0 (0)	0 (0)	102 (17.16)	132 (34.54)	492 (82.84)	251 (65.46)
3014	Manufacturing of pesticides	0 (0)	32 (4 11)	0 (0)	0 (0)	808 (67.16)	325 (41.27)	395 (32.84)	430 (56.43)
3024	Manufacturing of natural polymers & modified natural polymers in primary forms	0 (0)	0 (0)	0 (0)	0 (0)	402 (68.81)	492 (78.65)	182 (31.19)	133 (21.35)
3032	Manufacturing of paints, varnishes, enamels, etc.	0 (0)	0 (0)	0 (0)	0 (0)	77 (37.37)	34 (55.93)	130 (62.63)	27 (44.07)
3035	Manufacturing of printing, writing, drawing ink	0 (0)	0 (0)	0 (0)	0 (0)	56 (46 87)	96 (65.78)	63 (53.13)	50 (34.22)
3042	Manufacturing of allopathic pharmaceutical preparations	0 (0)	0 (0)	18 (2.80)	11 (0.99)	357 (56.47)	870 (75.31)	257 (40.73)	274 (23.70)
3043	Manufacturing of 'aurvedic' of 'unani' pharmaceutical preparations	0 (0.13)	3 (0 58)	0 (0)	49 (8.23)	330 (85 82)	454 (76.14)	54 (14.05)	90 (15.05)
3051	Manufacturing of toilet soaps	424 (71.78)	237 (44 66)	0 (0)	0 (0)	130 (21.95)	206 (38.81)	37 (6.27)	88 (16.53)
3059	Manufacturing of others (incl. scented sachets, etc)	1 (1 09)	1 (0 29)	7 (7.65)	17 (5.10)	49 (54 63)	234 (69.79)	33 (36.63)	83 (24.82)
30	Total	425 (9.66)	273 (5 92)	25 (0.56)	78 (1.68)	2311 (52.46)	2834 (61.54)	1644 (37.33)	1426 (30.86)

Note Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.36. Fuel-wise contribution of emissions from industry 30 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	226	145	0	0	2	16	228	161
SO_2	7	4	0	0	16	113	23	117
CO	1	1	0.01	0.02	2	12	3	13
HC	0	0	0	0	0	3	1	3
NO_x	7	4	0.06	0.20	20	137	26	141

5.3.1.3. Cotton textiles

Manufacture of cotton textiles (NIC code 23), though is not a major industry in Delhi, there are over 32 industries in operation during 1993/94. The only type of industry (NIC 4 digit level) under this category existing in Delhi is 2360 (Bleaching, dyeing and printing of cotton textiles).

An important observation on this sector is that the NVA has almost reduced to half (decreased by 48.46%) in this sector with a NVA of Rs 76.4 million in 1993/94 Table 5.37 while there has been a little decrease in the total energy consumption (11.22%) during this period. While both the two types of industries viz. 2350 and 2360 have shown a considerable decrease in NVA (48.9% and 38.1% respectively), the energy consumption decreased only in industry 2360 whereas there was no change in the energy consumption levels of industry 2350.

The large decrease in NVA and NVA/Input cost ratio (which has reduced from 0.414 to 0.210) is mainly due to the reduced production levels in the industry. While at the same time the gross value of plant and machinery has considerably gone down (by about 38.3% with a value of 113.3 million in 1993/94) during the same period keeping in the input cost at almost same level. This also signifies that the industry is labour intensive and hence the reduced production levels have mainly resulted in reduction of value addition while the input costs have not come down much. This is also evident from the large increase in energy intensity (which has increased by 72.26%, changed from 0.0663 to 0.1142 toe/thousand rupees) which is largely reflected through the increased energy intensity in industry 2350 (95.42%) which can be seen in Figure 5.40.

While the total energy consumption has declined by 12.64% (8725 toe in 1993/94), the energy mix has undergone a few changes which essentially include a shift from electricity to oil Table 5.38. The share of electricity has decreased from 49.6% to 31.72%, the share of coal has slightly increased (from 41.36% to 43.24%) and the share of oil has increased from 8.98% to 25.04%. Details of the fuel mix patterns indicate that the above trend is reflected mainly in industry 2350 in which the electricity share has decreased from 69.04% to 38.82%, the share of coal has increased from 21.95% and the share of oil has increased from 8.93% to 30.12%, while in case of 2360, which is a coal dominated industry, the share of coal has increased from 89.94% to 91.65%, the share of oil has decreased from 9.12% to 4.84% and the share of electricity has increased from 1.94% to 3.52%.

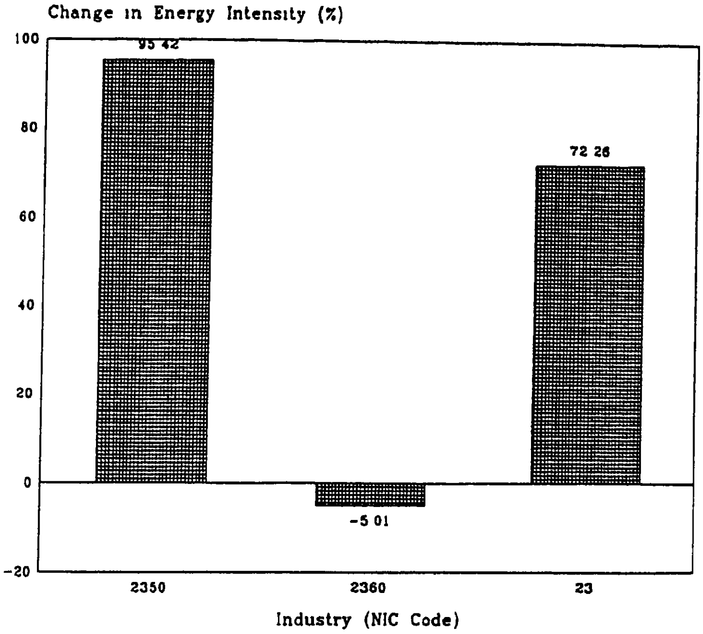


Figure 5.40. Changes in energy intensity of industry 23 during 1989/90 and 1993/94

The energy consumption analysis in this sector has revealed that, the decreasing trend in net value added and the increasing trend in energy intensity coupled with the fact that the input costs have remained at the same levels, indicates that the industry is on a declining trend, particularly the bleaching, dying and printing of cotton textiles (NIC 4 digit code 2360) which is seen as an environmentally non-benign trend.

The emissions from this sector have been estimated and it was found that the TSP from coal combustion is the main pollutant emitted from these industries besides SO_2, NO_x and CO from both coal and oil combustion. Annual emissions of TSP were found to be of the order 2048 tonnes. SO_2 were of the order 393 tonnes, NO_x 463 tonnes and CO 45 tonnes in 1993/94 Table 5.39. Between 1989/90 and 1993/94, the TSP emissions have come down by about 5%, SO_2, NO_x and CO emissions have increased by 419%, 497%, and 361% respectively. The decline in the industry coupled with the changes in the fuel mix during this period, especially the decreased consumption of coal, shift of fuel use from electricity to oil could be attributed to the resultant reduction in TSP and increased emission of the remaining pollutants. This trend is not encouraging from the point of view that it is not going to greatly contribute to the improved environmental status of the city.

Table 5.37. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 23 (manufacture of cotton textiles) in Delhi for the year 1989/90 and 1993/94

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2350	Cotton spinning, weaving and processing	6980	6969	143419	73281	330779	339295	176056	109784	0 0487	0.0951	0.434	0.216
2360	Bleaching, dyeing and printing of cotton textiles	2848	1755	4767	3093	27503	24224	7461	3508	0 5974	0.5674	0.173	0.128
23	Total	9827	8725	148186	76374	358282	363519	183517	113292	0 0663	0.1142	0.414	0.210

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.38. Total energy consumption and percentage shares of various fuels in sector 23 (manufacture of cotton textiles) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2350	Cotton spinning, weaving and processing	1532 (21 95)	2164 (31 05)	6 (0 08)	0 (0)	623 (8 93)	2099 (30.12)	4819 (69.04)	2706 (38.82)
2360	Bleaching, dyeing and printing of cotton textiles	2533 (88 94)	1609 (91 65)	0 (0)	0 (0)	260 (9 12)	85 (4 84)	55 (1.94)	62 (3.52)
23	Total	4065 (41 36)	3773 (43 24)	6 (0 06)	0 (0)	883 (8 98)	2184 (25 04)	4874 (49.60)	2767 (31.72)

Note: Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.39. Fuel-wise contribution of emissions from industry 23 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	2157	2002	0	0	2	46	2158	2048
SO_2	63	59	0	0	13	334	76	392
CO	8	8	0	0	1	37	10	45
HC	4	4	0	0	0	8	4	11
NO_x	62	58	0.01	0	15	405	78	462

5.3.1.4. Basic Metal and Alloys Industries

Manufacture of basic metal and alloys (NIC code 33) industry is also one of the major industry in Delhi with over 266 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows:

Industry Code	Type of industry
3301	Manufacturing of iron and steel in primary/semi-finished forms in the integrated plants
3309	Manufacturing of iron and steel in primary forms
3313	Manufacturing of wire-drawings of steel, alloy steel
3319	Manufacturing of semi-finished iron and steel
3330	Copper manufacturing
3340	Brass manufacturing
3370	Casting of metals

While analysing the data, for the years 1989/90 and 1993/94, the four digit level industries 3301, 3313 and 3319 were not considered since they were in losses (NVA was negative).

NVA by this sector has increased by 55.65% with a NVA of 67.2 million during 1993/94 Table 5.40 while the total energy consumption has also increased (by 40.76%) between 1989/90 and 1993/94. This, in the light of the fact that the input cost also has gone up by 29.1%, indicates that the production levels have increased in this sector. However, some varying trends have been observed in different types of industries within this sector. The major contributors of NVA in 1989/90 were 3330 (with a share of 54.12%) and 3340 (brass manufacturing with a share of 26%) and 3370 (with a share of 18.55%). The major contributors of NVA in 1993/94 are 3330 (with a share of 88.38%) in which the NVA has increased by 155%, and 3309 (with a share of 9.13%) in which the NVA has increased by about 960%, while the share of brass manufacturing and casting of metals has comedown considerably.

The large increase in NVA (55.65%) and a slight increase in NVA/Input cost ratio (which has increased from 0.138 to 0.166) is mainly due to increased production levels and also could be attributed to some structural changes and energy efficiency improvements, which is evident from the following facts; the gross value of plant and machinery has increased by about 13.54% with a value of 16.5 million in 1993/94. The energy intensity in this industry also has reduced from 0.0834 toe/thousand rupees in 1989/90 to 0.0754 toe/thousand rupees in 1993/94. The major investments in the plant and machinery have been in industries 3330 (for which the plant and machinery cost has increased by 40.7%) and 3340 (for which the plant and machinery cost has increased by 67.9%) while for the metal casting industry it has reduced considerably (by 366%). The energy intensities also have shown varying trends, but the overall trend in the industry showed a decline. Coming to the details, in the industry 3309 the energy intensity has increased from 0.1951 in 1989/90 to 0.4176 toe/thousand rupees in 1993/94 (a 114.08% increase), in 3330 the energy intensity has reduced from 0.0810 to 0.0369 toe/thousand rupees (a 54.43% decrease), in 3340 (brass manufacturing) the energy intensity has increased from 0.011 to 0.1152 toe/thousand rupees (a 948% increase) as can be seen in Figure 5.41. This indicates that the structural changes have essentially taken place in industries 3330 and 3340 while the energy efficiency improvements have taken place mainly in industry 3330.

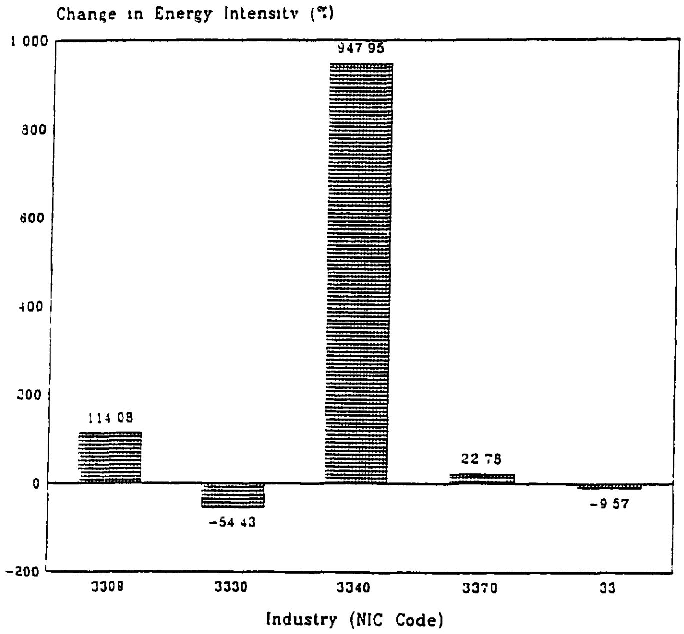


Figure 5.41. Changes in energy intensity of industry 33 during 1989/90 and 1993/94

While the total energy consumption has increased by about 29% (with 5066 toe consumption in 1993/94), the energy mix has undergone considerable changes during this period Table 5.41. There has been a major decline in coal consumption (32.04% to 5.28%), increase in electricity purchased (20.43% to 40.70%) and a slight increase in oil consumption (47.53% to 54.02%). However, different types of industries in this sector have shown varying shifting trends in energy mix as described here. But, in physical quantities, the fuel shifts have shown a clear trend from coal to electricity and/or oil. Industry 3309 and 3330 are the only two major energy consuming industries with a total share of 94% of the total energy consumed (5066 toe in 1993/94). The energy mix in industry 3309 has not undergone any change as observed, but in 3330, while there was no considerable use of coal and the oil share has reduced from 68.74% to 58.73 with a simultaneous increase in the share of electricity purchased from 31.26% to 40.15%.

From the energy consumption study of this sector it is interesting to learn that, the increasing trend in NVA, decreasing trend in energy intensity coupled with the shifts in energy mix from coal to electricity coupled with energy efficiency improvements, are good indicators of the industry's environmental performance which is expected to result in improved environmental conditions.

TSP from coal combustion is the main pollutant emitted from these industries besides SO_2, and NO_x emitted from both coal and oil combustion. Estimated annual emissions of TSP were found to be of the order 149 tonnes, SO_2 were of the order 55 tonnes and NO_x 65 tonnes in 1993/94 Table 5.42. Between 1989/90 and 1993/94, the TSP emissions have come down by about 76%, SO_2, and NO_x emissions have increased by 62%, and 77% respectively. The major changes which have taken place in the fuel mix during this period, especially the shift of fuel use from coal to oil and electricity could be attributed to the reduced TSP and increased emission of the remaining pollutants. This trend is certainly seen as positive and very good from the point of view of the reduced contribution of pollution emissions to the city's atmosphere and improving environmental performance of the industry.

Table 5.40. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 33 (basic metals and alloy industries) in Delhi for the year 1989/90 and 1993/94.

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3309	Manufacturing of iron and steel in primary forms	113	2560	578	6131	9435	126072	1140	0	0.1951	0.4176	0.061	0.049
3330	Copper manufacturing	1892	2192	23357	59367	220011	266081	8285	13977	0.0810	0.0369	0.106	0.223
3340	Brass manufacturing	123	68	11218	587	48413	6899	491	1531	0.0110	0.1152	0.232	0.085
3370	Casting of metals	1470	246	8004	1091	34973	4690	4614	989	0.1837	0.2256	0.229	0.233
33	Total	3599	5066	43157	67176	312832	403742	14530	16497	0.0834	0.0754	0.138	0.166

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.41. Total energy consumption and percentage shares of various fuels in sector 33 (basic metals and alloy industries) in Delhi during 1989/90 and 1993/94.

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3309	Manufacturing of iron and steel in primary forms	0 (0)	0 (0)	0 (0)	0 (0)	62 (54.56)	1400 (54.67)	51 (45.44)	1161 (45.33)
3330	Copper manufacturing	0 (0)	25 (1.12)	0 (0)	0 (0)	1301 (68.74)	1287 (58.73)	591 (31.26)	880 (40.15)
3340	Brass manufacturing	36 (29.01)	27 (39.84)	0 (0)	0 (0)	68 (54.86)	25 (37.47)	20 (16.14)	15 (22.69)
3370	Casting of metals	1117 (75.98)	216 (87.78)	0 (0)	0 (0)	280 (19.07)	24 (9.86)	73 (4.95)	6 (2.36)
33	Total	1153 (32.04)	268 (5.28)	0 (0)	0 (0)	1710 (47.53)	2736 (54.02)	735 (20.43)	2062 (40.70)

Note Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.42. Fuel-wise contribution of emissions from industry 33 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	612	142	0	0	2	7	614	149
SO_2	18	4	0	0	16	50	34	55
CO	2	1	0	0	2	6	4	6
HC	1	0	0	0	0	1	2	1
NO_x	18	4	0	0	19	61	37	65

5.3.1.5. Rubber, plastic, petroleum and coal products; processing of nuclear fuels

Manufacture of Rubber, plastic, petroleum and coal products (NIC code 31) is the major industry in Delhi with over 359 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows;

Industry Code	Type of industry
3100	Tyre tube industries
3111	Manufacturing of rubber footwear
3112	Manufacturing of plastic and PVC footwear
3113	Manufacturing of canvas-cum-rubber/plastic footwear
3121	Manufacturing of rubber plates, sheets, strips, rods, pipes, etc.
3129	Manufacturing of other rubber products

The detailed analysis has revealed that there was a very major increase (by almost 40 times) in NVA (with an increase of 3962%) in this industry with a NVA of 3940 million rupees in 1993/94 Table 5.43 whereas the total energy consumption has approximately doubled i.e.. increased by 92.97% (11915 toe in 1993/94). This huge increase in the NVA is mainly due to the sudden spur in the NVA from the NIC 4 digit industry 3129 in which there was an increase of 32674% in its NVA between 1989/90 and 1993/94 Excluding industry 3129, the NVA in industry 31 has considerably increased (i e.. more than doubled with an increase of 110%), while the increase in energy consumption is over 90%, which doesn't change much even after excluding the share of industry 3129 in which the energy consumption has actually reduced by about 50%. Excluding 3129, the major contributors to the NVA in this industry (in 1993/94 also) continue to be 3100 with a share of 26.6%, 3111 with a share of 17 8%, and 3113 with a share of 44 4%.

The increase in NVA (3692% including industry 3129 and 110% excluding 3129), coupled with increase in NVA/input cost ratio which has increased from 0.198 in 1989/90 to 2.554 (including industry 3129) indicates that the industry has undergone structural changes particularly in the form of shift towards value added products. The NVA/input cost ration decreased to 0.132 when excluded 4 digit industry 3129 in 1993/94, this coupled with the increase in NVA and in the light of huge increase in the input cost (215.3%) and gross value of plant and machinery (64%) indicate that there have been some structural changes including technological improvements. There has been, particularly, increase in plant and machinery cost in industries 3111 (42.18%) and 3113 (354.82%) while in other major contributors on NVA, there has been no significant change, excluding 3129 for which the plant and machinery has gone down by 71.8%. This is reflected in the reduced energy intensity (reduced from 0.0637 to 0.0030 toe/thousand rupees when included industry 3129, 0.0585 when excluded industry 3129). However, some changes (increase or decrease) in the energy intensity of the industries which are the major contributors to value addition have been observed, which on the whole have resulted in a reduced energy intensity of this industry. Viz., the energy intensity in 3129 has reduced by 99.85%, in 3100 has increased by 38.52%, in 3111 has reduced by 14%, in 3113 has increased by 46.4% Figure 5.42.

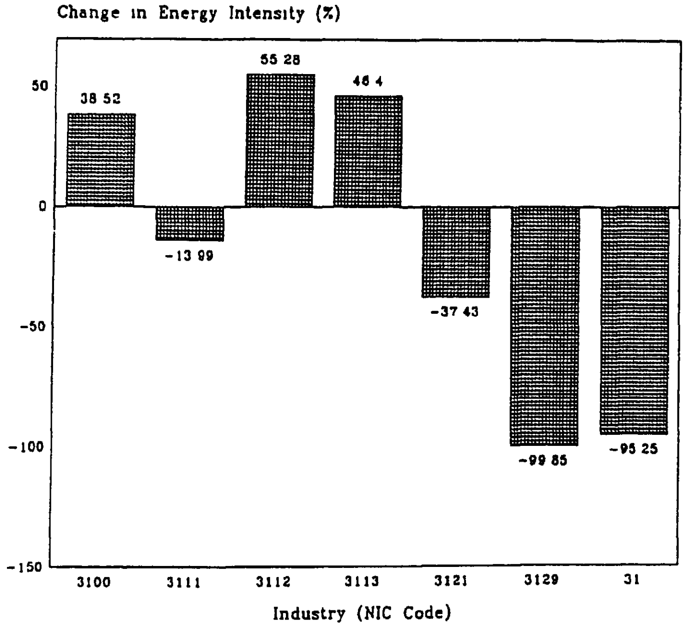


Figure 5.42. Changes in energy intensity of industry 31 during 1989/90 & 1993/94

While there has been a considerable increase in total energy consumption (92.97%), the energy mix has also undergone some changes in terms of shift from coal to oil in the overall industry during 1989/90 and 1993/94 when the coal share has decreased from 55 62% to 33.53%, the oil share has increased from 16.06% to 40.84% while the share of electricity has marginally decreased from 28.30% to 25.63% Table 5.44. A detailed analysis of the energy mix trends within the industries in this sector showed that, the coal share has decreased (and the share of oil has increased or decreased in some cases) in all the major contributors to NVA in this sector viz., in 3111, the coal share has reduced from 52.43% to 11.36% and the share of oil has increased from 20.18% to 61.44% while the share of electricity purchased has remained at 27.2%; in 3113 the coal share has reduced from 50.83% to 25.39% and the share of oil has increased from 18.56% to 47.92% while the share of electricity purchased has decreased marginally from 30.61% to 26.69%; in case of 3129, the coal share of reduced from 73.41% to 32.10% and the share of oil has increased from 5.51% to 50% while the share of electricity purchased has marginally decreased from 21.07% to 17.90%.

The main observation from the energy consumption analysis is that, the increasing trend in NVA and the decreasing trend in energy intensity coupled with the trends in shifts of fuels from coal to oil or electricity are good indicators of better performance of the industry from environmental point of view along with energy efficiency improvements, which all together indicate encouraging growth trends of the industry heading for technological improvements through structural changes.

The emissions from this sector have been estimated using appropriate emission factors and it was found that the TSP from coal combustion is the main pollutant emitted from these industries besides SO_2, NO_x and CO from both coal and oil combustion. Annual emissions of TSP were found to be of the order 2137 tonnes, SO_2 were of the order 182 tonnes, NO_x 206 tonnes and CO 21 tonnes in 1993/94 Table 5.45. Between 1989/90 and 1993/94, the TSP, SO_2, NO_x and CO emissions have increased by 17%, 123%, 138% and 112% respectively. The changes in the fuel mix during this period, especially the shift of fuel use from coal to oil and electricity could be attributed to the reduced TSP and increased emission of the remaining pollutants. This trend is certainly seen as positive and good from the point of view of the reduced contribution of pollution emissions to the city's atmosphere and improving environmental performance of the industry.

Table 5.43. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 31 (manufacture of rubber, plastic, petroleum and coal products) in Delhi for the year 1989/90 and 1993/94

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3100	Tyre tube industries	1344	3808	26540	54285	79133	163308	11030	10091	0.0506	0.0701	0.335	0.332
3111	Manufacturing of rubber footwear	1723	2434	22044	36192	138209	226289	13407	19602	0 0782	0.0672	0.160	0.160
3112	Manufacturing of plastic and PVC footwear	370	784	13236	18044	94142	191637	14483	14160	0 0280	0.0434	0.141	0.094
3113	Manufacturing of canvas-cum-rubber/plastic footwear	483	3856	16573	90380	98053	845092	16785	76340	0.0291	0 0427	0.169	0.107
3121	Manufacturing of rubber plates, sheets, strips, rods, pipes, etc.	960	393	7211	4714	42516	38361	11128	6114	0 1331	0.0833	0.170	0.123
3129	Manufacturing of other rubber products	1294	641	11402	3736757	37175	77994	11919	3362	0 1135	0.0002	0.307	47.911
31	Total	6175	11915	97007	3940372	489228	1542681	78753	129129	0.0637	0.0030	0.198	2.554

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.44. Total energy consumption and percentage shares of various fuels in sector 31 (manufacture of rubber, plastic, petroleum and coal products) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3100	Tyre tube industries	696 (51.77)	2456 (64.49)	1 (0.08)	0 (0)	303 (22.58)	689 (18.08)	344 (25.57)	663 (17.42)
3111	Manufacturing of rubber footwear	904 (52.43)	276 (11.36)	0 (0)	0 (0)	348 (20.18)	1495 (61.44)	472 (27.39)	662 (27.20)
3112	Manufacturing of plastic and PVC footwear	0 (0)	0 (0)	0 (0)	0 (0)	87 (23.52)	395 (50.36)	283 (76.48)	389 (49.64)
3113	Manufacturing of canvas-cum-rubber/plastic footwear	245 (50.83)	979 (25.39)	0 (0)	0 (0)	90 (18.56)	1848 (47.92)	148 (30.61)	1029 (26.69)
3121	Manufacturing of rubber plates, sheets, strips, rods, pipes, etc	639 (66.63)	78 (19.97)	0 (0)	0 (0)	92 (9.61)	119 (30.25)	228 (23.76)	195 (49.77)
3129	Manufacturing of other rubber products	950 (73.41)	206 (32.10)	0 (0)	0 (0)	71 (5.51)	321 (50.01)	273 (21.07)	115 (17.90)
31	Total	3434 (55.62)	3995 (33.53)	1 (0.02)	0 (0)	992 (16.06)	4866 (40.84)	1747 (28.30)	3054 (25.63)

Note: Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.45. Fuel-wise contribution of emissions from industry 31 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	1822	2120	0	0	4	17	1826	2137
SO_2	53	62	0	0	28	120	81	182
CO	7	8	0	0	3	13	10	21
HC	4	4	0	0	1	3	4	7
NO_x	53	61	0	0	34	145	87	206

5.3.1.6. Non-metallic mineral products

Manufacture of non-metallic mineral products (NIC code 32), though is not a major industry in Delhi, there are over 67 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows;

Industry Code	Type of industry
3219	Manufacturing of other glassware/ glass products
3292	Manufacturing of concrete tiles
3293	Manufacturing of hum pipes and other pre-fabricated structural components

In this industry, during 1989/90 and 1993/94, there was a marginal increase in the NVA (10.23%) with a NVA of 46.1 million rupees in 1993/94 compared to the increase in total energy consumption (53.13%) in this sector Table 5.46. The major contributor to NVA continues to be the industry 3293 with a lions share of 88% in 1993/94 while the industry 3219 contribute about 9% NVA. The increase in NVA in this sector is largely because of the increase in the 4 digit industries 3219 (125.38% amounting to 23.2 million rupees) and 3293 (5.82% amounting to 22.3 million rupees) while the energy consumption in these industries has increased respectively by 532.1% and 12.1%. This indicates that the production levels have been increased in this industry.

The increase in NVA and the increase in NVA/input cost ratio (which has increased from 0 215 to 0.314) mainly leads to the conclusion that there has been some structural change in the form of technological improvements. This is also evident from the decreasing input costs in this sector (reduced by 23.16%) which is of the order 62.3% reduction in the industry 3219 and 16.51% in the industry 3293. Further, the energy intensities in this sector have shown an increasing trend with an increase of 39% in the overall sector, while in industry 3219 it was of the order 180.5%, in 3293 it was of the order 6% Figure 5.43.

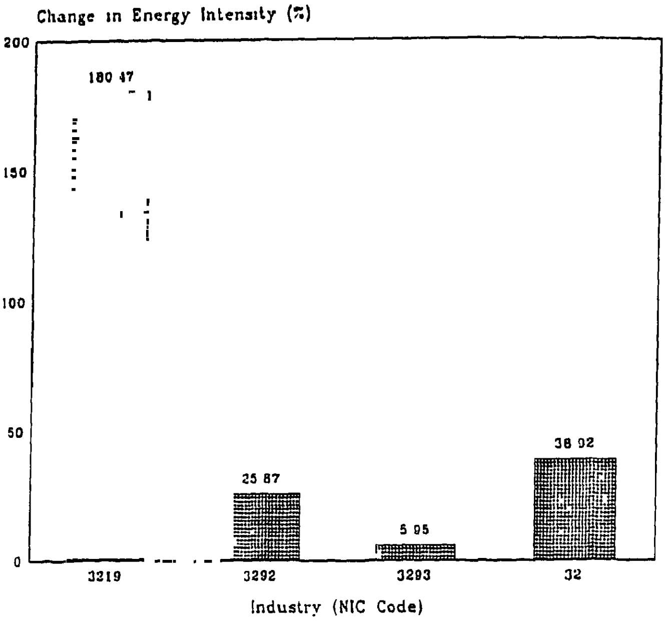


Figure 5.43. Changes in energy intensity of industry 32 during 1989/90 & 1993/94

While there has been a marginal increase in the total energy consumed (10.23%), there has been a slight shift in the energy mix with a small increase in coal (from 45.76% to 49.3%) and oil consumption share (from 32.42% to 38.76%) and a small decrease in the share of the electricity purchased (from 21.82% to 12%) as can be seen in Table 5.47. These trends continued in the 4 digit level industries also, particularly in case of the major contributors to value addition which also happen to consume energy in similar proportions. In case of industry 3219, the share of oil has increased from 51.52% to 94.94% while the share of electricity decreased from 48.48% to 5.06%; in case of industry 3293, the share of coal increased from 52.39% to 77.09%, the share of electricity reduced from 19.42% to 13.86% and the share of oil too reduced from 28.19% to 9.05%. However, the increase in coal consumption could also be attributed to the growth in the number of coal consuming industries, thus resulting in changes in the overall energy mix.

The energy consumption analysis of this sector has revealed that, the marginal increase in NVA, increase in energy intensities coupled with the shifts in energy mix, particularly increase in coal consumption is not good a indicator of the environmental performance of the sector which might have negative implications on the environment.

The emissions from this sector have been estimated. TSP from coal combustion is the main pollutant emitted from these industries besides SO_2 and NO_x in small quantities from both coal and oil combustion. Annual emissions of TSP were found to be of the order 363 tonnes, SO_2 were of the order 24 tonnes and NO_x 27 tonnes in 1993/94 Table

5.48. Between 1989/90 and 1993/94, the emissions of TSP, SO_2, and NO_x have increased by 66%, 153%, and 166% respectively. The changes in the fuel mix during this period, especially the decreased consumption of coal and shift of fuel use from electricity to oil could be attributed to the resultant reduction in TSP and increased emission of the remaining pollutants. This trend is not encouraging from the point of view that it is not going to greatly contribute to the improved environmental status of the city.

Table 5.46. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 32 (manufacture of non-metallic mineral products) in Delhi for the year 1989/90 and 1993/94

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3219	Manufacturing of other glassware /glass products	72	453	1848	4164	24647	9290	235	1627	0.0388	0.1088	0.075	0.448
3292	Manufacturing of concrete tiles	43	45	1672	1403	6175	3724	1695	1225	0.0254	0.0320	0.271	0.377
3293	Manufacturing of hum pipes and other pre-fabricated structural components	787	883	38332	40564	160523	134020	12931	12901	0.0205	0.0218	0.239	0.303
32	Total	902	1381	41582	46131	191345	147034	14860	15753	0.0215	0.0299	0.219	0.314

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.47. Total energy consumption and percentage shares of various fuels in sector 32 (manufacture of non-metallic mineral products) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
3219	Manufacturing of other glassware/ glass products	0 (0)	0 (0)	0 (0)	0 (0)	37 (51.52)	430 (94.94)	35 (48.48)	23 (5.06)
3292	Manufacturing of concrete tiles	0 (0)	0 (0)	0 (0)	0 (0)	33 (78 59)	25 (56.10)	9 (21.41)	20 (43.90)
3293	Manufacturing of hum pipes and other pre-fabricated structural components	413 (52.39)	681 (77 09)	0 (0)	0 (0)	222 (28.19)	80 (9 05)	153 (19.42)	122 (13.86)
32	Total	413 (45.76)	681 (49.29)	0 (0)	0 (0)	292 (32.42)	535 (38 76)	197 (21.82)	165 (11.95)

Note Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.48. Fuel-wise contribution of emissions from industry 32 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	219	361	0	0	0	2	219	363
SO_2	6	11	0	0	3	13	9	24
CO	1	1	0	0	0	1	1	3
HC	0	1	0	0	0	0	0	1
NO	6	10	0	0	4	16	10	27

5.3.1.7. Man-made fibers

Manufacture of man-made fibres (NIC code 24) is not a major industry in Delhi, and there are only about 21 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows;

Industry Code	Type of industry
2430	Bleaching and dyeing of woolen textiles
2460	Bleaching and dyeing of silk textiles
2471	Spinning of staple fibers in mills

There is a slight decline in the NVA (21%) with a value addition of 18.7 million rupees in 1993/94, while the total energy consumption has increased considerably (by 83.9%) during the same period Table 5.49. There is a similar decline in NVA of the major NVA contributing industries viz., 2471 whose share of NVA is of the order 86.14% and the NVA has declined by 20.66% in 1993/94, 2460 whose share of NVA is 14% and the NVA has declined by 18.91%.

The decrease in NVA (21%), the decrease in NVA/input cost ratio (which has gone down from 0.243 to 0.193), and the input cost which remained almost at the same level (96.9 million rupees in 1993/94), indicates that there has been some decline in the performance of the industry When analysed the 4 digit level industries, the NVA/input cost ratio has gone up from 0.349 to 0.619 in case of industry 2460 while it has decreased from 0.232 to 0.179 in case of industry 2471. At the same time, interestingly, the gross value of plant and machinery has increased considerably in this industry (by 520%). This total increase is mainly due to the increase in plant and machinery cost of industry 2471 for which the plant and machinery cost was -0.218 million rupees in 1989/90 which has increased to 8.91 million rupees in 1993/94. The energy intensity in this sector has, however, increased considerably (by 132.65%) with energy intensity of 0.1191 toe/thousand rupees. An important observation is that in the industry 2471, which happens to contribute heavily to the NVA, there has been an increase of 235.52% in the energy intensity with a value of 0.0655 toe/thousand rupees Figure 5.44. And in case of industry 2460, the energy intensity has increased by over 100% with a value of 0.1624 toe/thousand rupees in 1993/94. This indicates that there have been some structural changes in the form of technological improvements.

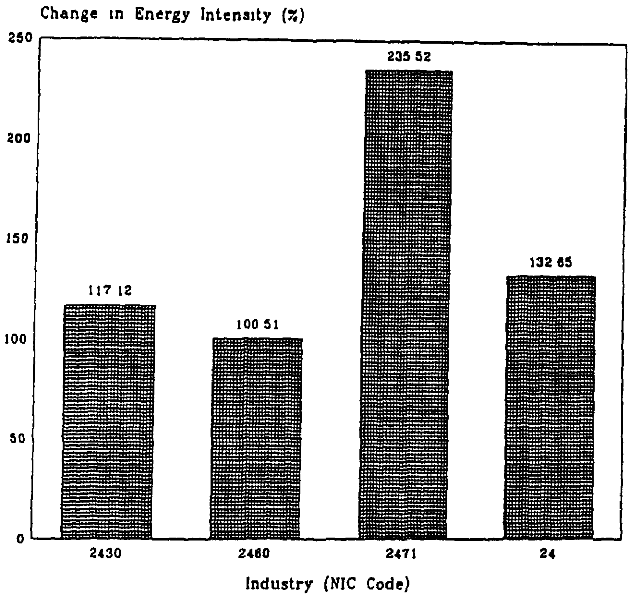


Figure 5.44. Changes in energy intensity of industry 24 during 1989/90 & 1993/94

While the energy consumption has increased considerably (by 83.87%) with a total energy consumption of 2227 toe in 1993/94, the energy mix has undergone some minor changes with a decline in coal share and increase in oil and electricity shares. There has been a slight decline in the share of coal from 84.27% to 63.13% and a slight increase in the share of oil from 8.37% to 22.39% and an increase in the share of electricity purchased from 7.36% to 14.49%. The details of fuel shares in 4 digit level industries also follow the same trends which is evident from Table 5.50 the following; there is a major decline in coal share from 63.18% to 31.49% in industry 2471 in which the oil share has increased from 20.24% to 44.12% and the share of electricity has increased from 16.57% to 24.38%; in industry 2460 and 2430, the fuel shares have remained almost at the same levels with insignificant changes. The changes in energy mix in industry 2471 might be a result of technological interventions, which is evident from the increased plant and machinery cost. however, what remains unclear is the fact that despite technological interventions, there has been no significant change in the energy intensity.

The energy consumption analysis has revealed that, the increasing trend in the energy intensity and the decreasing trend in the net value added coupled with the increasing trend in the overall energy consumption are not good indicators of the performance of the industry leading to negative environmental implications.

TSP from coal combustion is the main pollutant emitted from these industries besides SO_2 and NO_x from both coal and oil combustion. Estimated annual emissions of TSP were found to be of the order 747 tonnes (mainly from coal combustion), SO_2 were of the order 28 tonnes and NO_x 29 tonnes in 1993/94. Between 1989/90 and 1993/94, the emissions of TSP, SO_2, and NO_x have increased by 38%, 49%, and 51% respectively. The changes in the fuel mix during this period, especially the decreased consumption of coal and shift of fuel use from electricity to oil could be attributed to the resultant reduction in TSP and increased emission of the remaining pollutants. This trend is not encouraging from the point of view that it is not going to greatly contribute to the improved environmental status of the city.

Table 5.49. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 24 (manufacture of man-made fibers) in Delhi for the year 1989/90 and 1993/94

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2430	Bleaching and dyeing of woolen textiles	603	827	738	466	2389	3271	1215	1483	0.8167	1.7732	0.309	0.143
2460	Bleaching and dyeing of silk textiles	212	345	2621	2125	7508	3433	819	861	0.0810	0.1624	0.349	0.619
2471	Spinning of staple fibers in mills	396	1055	20306	16111	87533	90171	-218	8914	0.0195	0.0655	0.232	0.179
24	Total	1211	2227	23665	18703	97430	96876	1816	11258	0.0512	0.1191	0.243	0.193

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.50. Total energy consumption and percentage shares of various fuels in sector 24 (manufacture of man-made fibers) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2430	Bleaching and dyeing of woolen textiles	584 (96.85)	757 (91.56)	0 (0)	0 (0)	11 (1.85)	15 (1.84)	8 (1.30)	55 (6.60)
2460	Bleaching and dyeing of silk textiles	187 (87.92)	317 (91.68)	0 (0)	0 (0)	10 (4.73)	18 (5.17)	16 (7.35)	11 (3.15)
2471	Spinning of staple fibers in mills	250 (63.18)	332 (31.49)	0 (0)	0 (0)	80 (20.24)	465 (44.12)	66 (16.57)	257 (24.38)
24	Total	1021 (84.27)	1406 (63.13)	0 (0)	0 (0)	101 (8.37)	499 (22.32)	89 (7.36)	323 (14.49)

Note Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.51. Fuel-wise contribution of emissions from industry 24 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	542	746	0	0	0	1	542	747
SO$_2$	16	22	0	0	3	6	19	28
CO	2	3	0	0	0	1	2	4
HC	1	1	0	0	0	0	1	2
NO	16	22	0	0	3	7	19	29

5.3.1.8. Paper and paper products

Manufacture of paper and paper products (NIC code 28) industry is also one of the major industry in Delhi with over 355 industries in operation during 1993/94. The various types of industries (NIC 4 digit level) under this category existing in Delhi are as follows:

Industry Code	Type of industry
2810	Manufacture of containers and boxes
2840	Printing and publishing of newspapers
2850	Printing and publishing of periodicals, books

It is interesting to note from the analysis that there is some increase in the NVA (27%) during 1989/90 and 1993/94 with a NVA of 557.3 million rupees in 1993/94 while the energy consumption has increased considerably (by 61.1%) in the same period Table 5.52. There was a significant increase in the NVA of industry 2840 by 68.19% while there has been some decline (of the order 45.61%) in the NVA of industry 2850, while both these industries contribute major share of NVA in this sector (81.6% by 2840 and 15.1% by 2850 in 1993/94).

The increase in NVA coupled with marginal increase in NVA/input cost ratio (which has gone up from 0.502 to 0.547), mainly leads to the conclusion that there have been some structural changes in this sector in the form of technological interventions. While the energy intensity in this industry has slightly increased by about 26.88% (with a value of 0.0076 toe/thousand rupees in 1993/94, the plant and machinery cost also has increased by about 36% during the same period. However, it is important to note that the energy intensity has considerably decreased (by about 40.36%) with a value of 0.0031 toe/thousand rupees in 1993/94 in industry 2840 which is the major contributor to NVA (with a share of 81.6) in which the plant and machinery cost has increased marginally by 18.27% keeping the input cost the same level in the period under investigation. At the same time, the energy intensity in industry 2850 has increased by about 366% with a value of 0.0281 in 1993/94 in which case the total energy consumption, input costs and gross value of plant & machinery have increased by 153.4%, 93.23% and 103.8% respectively. While in case industry 2810 there has been a 32.8% increase in NVA, 55.6% increase in total energy and 17.16% increase in energy intensity, keeping the NVA/input cost ratio unchanged (with a value of 0.157 in 1993/94. This clearly indicates that the technological changes have taken place essentially in industry 2840 and 2810 in which the changes in energy intensity are marginal Figure 5.45.

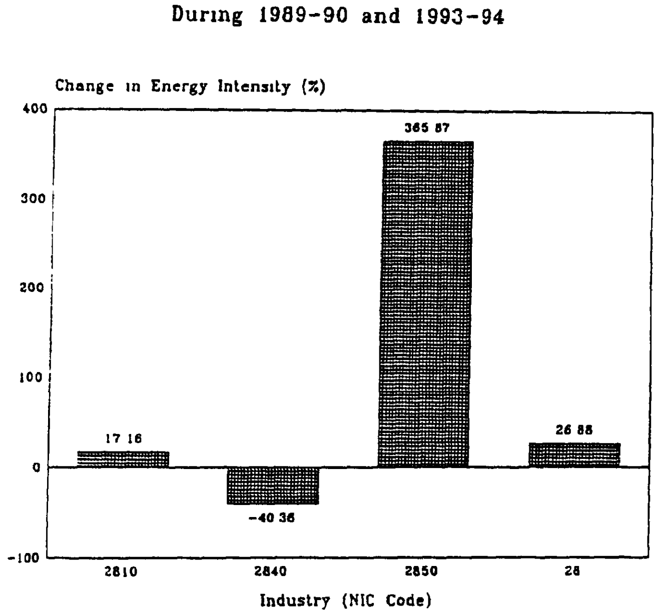


Figure 5.45. Changes in energy intensity of industry 28 during 1989/90 & 1993/94

While there has been a major increase (61.1%) in total energy consumption (from 2645 toe to 4261 toe), the energy mix has almost remained unchanged with major dependence on electricity and oil Table 5.53. In the industry 2840, the major contributor to value addition, the share of electricity has declined marginally from 81.62% to 75.73% while the share of oil has increased from 18.38 to 24.27%. In case of industry 2850, the share of electricity has increased from 54.71% to 60.18% while the share of oil has decreased from 43.7% to 39.6%.

From the energy consumption analysis, it is interesting to note that, the increasing trend in NVA and increasing trend in energy intensity which are of the same order (26.9% increase) indicate that the technological interventions have no direct bearing on the energy consumption and the associated implications.

The emissions from this sector have been estimated using appropriate emission factors and it was found that SO_2 from oil combustion is the main pollutant emitted from these industries. Besides this, TSP and NO_x and CO are the other emissions from oil combustion. Annual emissions of TSP were found to be of the order 17 tonnes, SO_2 were of the order 122 tonnes, NO_x 147 tonnes and CO 13 tonnes in 1993/94 Table 5.54. Between 1989/90 and 1993/94, the emissions of TSP, SO_2, NO_x and CO have increased by 1271%, 1272%, 1267% and 1266% respectively. Particularly the increase in SO_2 and NO_x are very high causing concern. The increased number of industries seems to be the main cause of the increased emissions of the pollutants from the industries in this sector. However, this trend is not encouraging from the point of view that it is not going to greatly contribute to the improved environmental status of the city.

Table 5.52. Energy Intensity, value addition, input cost and gross value of plant and machinery for sector 28 (manufacture of paper and paper products) in Delhi for the year 1989/90 and 1993/94.

Industry Code	Type of industry	Total Energy Consumption (toe)		Net Value Added (Rs Thousands)		Input Cost (Rs Thousands)		Gross Value of Plant & Machinery (Rs Thousands)		Energy Intensity (toe/Rs Thousands)		NVA/Input Cost	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2810	Manufacture of containers and boxes	328	511	13931	18502	90820	117805	13147	15995	0.0236	0.0276	0.153	0.157
2840	Printing and publishing newspapers	1385	1389	270358	454705	644321	630476	380930	450516	0.0051	0.0031	0.420	0.721
2850	Printing and publishing of periodicals,books,etc.	932	2361	154554	84065	139714	269968	102654	209167	0.0060	0.0281	1.106	0.311
28	Total	2645	4261	438843	557271	874856	1018294	496731	675678	0.0060	0.0076	0.502	0.547

All the values (for NVA, input and plant & machinery) are in constant prices with 1981/82 as the base year

Table 5.53. Total energy consumption and percentage shares of various fuels in sector 28 (manufacture of paper and paper products) in Delhi during 1989/90 and 1993/94

(Energy consumption in tonnes of oil equivalent)

Industry Code	Type of industry	Coal		Natural gas		Oil		Electricity purchased	
		1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
2810	Manufacture of containers and boxes	0 (0)	0 (0)	0 (0)	0 (0)	193 (58 70)	263 (51 47)	136 (41.30)	248 (48.53)
2840	Printing and publishing of newspapers	0 (0)	0 (0)	0 (0)	0 (0)	254 (18 38)	337 (24.27)	1130 (81.62)	1052 (75.73)
2850	Printing and publishing of periodicals, books	0 (0)	0 (0)	15 (1.59)	5 (0 23)	407 (43 70)	935 (39 59)	510 (54 71)	1421 (60.18)
28	Total	0 (0)	0 (0)	15 (0.56)	5 (0 13)	854 (32 30)	1535 (36 02)	1776 (67.13)	2721 (63.85)

Note: Numbers in brackets indicate the percentage shares of the respective fuels

Table 5.54. Fuel-wise contribution of emissions from industry 28 in Delhi

Pollutant	Coal		Natural Gas		Oil		Total	
	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94	1989/90	1993/94
TSP	0	0	0	0	1	17	1	17
SO_2	0	0	0	0	9	122	9	122
CO	0	0	0	0	1	13	1	13
HC	0	0	0	0	0	3	0	3
NO_x	0	0	0.04	0.02	11	147	11	147

CHAPTER 6

Summary and conclusions

This study has made an attempt to develop a methodological framework for analyzing the energy consumption pattern in the transport, power and manufacturing industrial sector in the four large Indian metropolitan cities viz., Delhi, Calcutta, Mumbai and Bangalore. The framework for analyzing the resultant emissions of CO, HC, NO_x, SO_2, TSP and Pb due to energy use in the three sectors has also been developed. The framework provided in this study represents a starting point for understanding the complex and related issues of energy use and emissions from each of the three sectors at the city level and can be applied to a spectrum of large cities in Asia.

Secondary data has been collected, compiled and analyzed to understand the trends relating to the demographic, sectoral energy use and air quality characteristics in each of the four cities. In view of the proposed framework, information has been generated by analyzing the secondary data which is finally used to estimate the present and future energy consumption pattern and resultant emissions from each of the three sectors. In the transport sector the energy-environment analysis is carried out for all the four cities as the requisite data could be compiled at the city levels. While, in power sector, due to the non availability of any major power station located within Bangalore city limits, the analysis is restricted to Delhi, Calcutta and Mumbai. Similarly, in the case of industries, as the most disaggregated data is available at the state level, only the city of Delhi (which also is a State) is considered for the energy-environment analysis. Further, in industries the analysis is restricted to the top few energy intensive industries located within the city limit of Delhi.

The study has also examined the reduction potential of energy use and emissions at the city level by analyzing a set of policy issues (as alternative scenarios) each of which are compared with the base line results. Base line refers to the business-as-usual (BAU) scenario, which is generally defined as the future is simply an extrapolation of "more of the same" of the present in terms of technology and economic structures and based on the currently perceived incentives. For instance, in this study, BAU scenario in the transport sector is defined as the present trends of growth in the vehicular registration in cities would continue, while the present average fuel efficiency norms, occupancy level or load factor and vehicle utilization pattern for different modes of transport will remain unchanged in the coming years. However, two mutually reinforcing transport policies as alternative scenarios are considered to try to reduce energy use in transport and vehicular pollution: (1) reduce urban congestion by say, strengthening mass transport facilities which would help in facilitating a shift from use of personalized vehicles to public buses, and (2) promote cleaner fuels (like introduction of compressed natural gas, or propane or even battery operated vehicles) and engine technologies (like, phasing out of two-stroke which could be replaced with four stroke engines). Similar approach in defining the BAU and alternative scenarios are considered in the power and industrial sector, discussed later in this chapter.

6.1. Growth of cities and population density

Over the last few decades, the cities experienced rapid expansion due to various economic activities. According to the last census report, the population in the four cities during 1990/91 were Delhi 9.42 million, Calcutta 11.86 million, Mumbai 9.93 million and Bangalore 4.09 million respectively. The compound average annual growth rate of population between 1981 and 1991 was 4.24%, 1.61%, 1.88% and 3.43% respectively. However, in the current decade (i.e., 1991-2001) it is expected that the corresponding growth rates would decline to 2.5%, 1.6%, 1.8% and 3.4% respectively. These are further expected to decline to 1.8%, 1.4%, 1.6% and 3% respectively in the next decade. This indicates that population size of Delhi in 2010/11 would be over 14 million, which is over 50% increase with respect to 1990/91 level. The corresponding figures for Calcutta, Mumbai and Bangalore are about 16 million (35% increase with the 1990/91 level), 14 million (40% increase) and 8 million (87% increase) respectively.

The average population density of Delhi, Calcutta metropolitan area (in short Calcutta), Mumbai metropolitan region and Bangalore in 1990/91 is estimated to be 6352, 8594, 3463 and 9212 persons per square kilometre. While, the average population densities in Calcutta city and Greater Mumbai (in short Mumbai) centres are relatively very high i.e., 23670 and 33100 persons per square kilometre in 1990/91.

Given below is a summary of major findings and some policy recommendations directed towards ameliorating the air pollution in cities.

6.2. Transport sector

6.2.1. Growth and composition of registered vehicles

With over 2.4 million registered vehicles in Delhi as on 30th March 1995, the city has the largest vehicle population in the country even though it ranks third in the list of megacities in the country after Mumbai and Calcutta. It is interesting to note that the vehicle population of Mumbai (0.67 million), Calcutta (0.56 million) and Bangalore (0.8 million) taken together accounts for 2.03 million vehicles which is even less than the vehicle population of Delhi alone during 1994/95.

The annual registration of motor vehicles in the four cities went up at an average growth rate of 11.2% in Delhi, 7% Calcutta, 4.5% in Mumbai and 11.1% in Bangalore between 1984/85 and 1990/91. But, these growth rates declined between 1990/91 and

1994/95 to 7.8%, 4.2%, 1.5% and 8.4% in Delhi, Calcutta, Mumbai and Bangalore respectively. In absence of a convenient and well connected public mass transport system in the four cities, the growth of personal modes like scooters, motorcycles and cars have grown rapidly. The autorickshaw as the intermediate public transport system has also grown very rapidly in late 1980s mainly in Calcutta and Bangalore. In 1994/95, the share of scooters and motorcycles together accounted for 75% of the total registered vehicles in Bangalore, 70% in Delhi, while in Calcutta and Mumbai its share accounted for 44% and 42% respectively. During the same period, the share of car and jeep taken together was 37% in Calcutta, 35% in Mumbai, 25% in Delhi and 14% in Bangalore. This means that the share of personalized modes in the four cities was highest in Delhi at 95% and least in Mumbai at 77% during 1994/95. Unfortunately, the share of public mass transport (that of a bus) has been declining in Delhi and Bangalore with its current share only around 1%, while in Calcutta and Mumbai, its share has been increasing with current share being 2.4% and 1.8% respectively. As far as goods vehicles are concerned their share has been declining in the total fleet size in each of the four cities. In 1994/95, its share was 5.14% in Delhi, 8.29% in Calcutta, 6.18% in Mumbai and 4.8% in Bangalore respectively.

6.2.2. Vehicle projections with attrition factor

Without altered policies and assuming an attrition factor (or vintage value) of 15 years for a scooter and motorcycle, 20 years for an autorickshaw, 25 years for a car, taxi and jeep, and 10 years for a bus, it is estimated that Delhi is expected to have 2.4 million passenger vehicles plying on Delhi roads in 2000/01 and 2.8 million in 2010/11. The corresponding figures for Calcutta are 0.44 million and 0.53 million, Mumbai 0.42 million and 0.73 million; Bangalore 0.65 millon and 0.97 million respectively. In other words, number of motorized passenger vehicles - with assumed attrition factor for different types of modes - is expected to increase by 40% in Delhi, 19% in Calcutta, 77% in Mumbai and 49% in Bangalore between 1995/96 and 2010/11.

6.2.3. Ownership pattern of vehicles

Average ownership of private vehicles in Delhi was found out to be the maximum with 178 vehicles per 1000 persons in 1995/96. Bangalore followed the list with 127, Calcutta and Mumbai each with 31 vehicles per 1000 persons.

6.2.4. Passenger travel demand

The total passenger travel demand in Delhi is estimated to increase over 3 fold - from about 47 billion passenger kilometre (bpkm) in 1990/91 to 143 bpkm in 2010/11. In Calcutta, with passenger travel demand in 1990/91 about 12 bpkm, is estimated to increase over 1.3 times by 2010/11. In Mumbai, the increase would be over double between 1990/91 (16 bpkm) and 2010/11. While in Bangalore, the increase would be nearly 4 times - from 14 bpkm in 1990/91 to 54 bpkm in 2010/11. With only around 1 to 2% of the total fleet size being bus in the four cities, it currently caters to over 53% of the total travel demand in Delhi, 32% in Calcutta, 67% in Bangalore and 80% in Mumbai respectively. By the year 2010/11, the travel demand share by buses are expected to increase to 66% in Delhi, while that in Calcutta and Bangalore its share would decline to 26% and 59% respectively. In Mumbai, the share of travel demand by bus is assumed to remain at the current level.

6.2.5. Framework for analysis

A simple transport model has been formulated using a computer based software called - Long Range Energy Alternatives Planning (LEAP) and the associated Environmental Database. LEAP is an energy-environment planning system developed by the Stockholm Environment Institute, Boston. LEAP is an accounting framework within which the user can create models of demand and supply. The central concept of LEAP is an end-use driven scenario analysis. In this model, the computer system is used to analyze the current energy scene and to simulate alternative energy futures along with emissions under a range of user-defined assumptions.

The driving forces considered in LEAP for analyzing energy demand are growth in registration of motor vehicles adjusted with assumed attrition factors or vintage, penetration of different technologies, average utilization, occupancy or load factor and operating energy intensity The resultant mass emissions of CO, HC, NO_x, SO_2, TSP and Pb are estimated using LEAP by multiplying energy consumption by different modes -- further broken down into technologies -- and their corresponding emission factors. Five reference years viz., 1990 91, 1995/96, 2000/01, 2005/06 and 2010/11 are considered for analysis.

6.2.5.1. Total and per capita energy demand

Demand of gasoline and diesel for transportation of personal and goods mobility would increase 2.5 times in Delhi in the BAU scenario - from 0.69 million tonnes of oil equivalent (mtoe) in 1990/91 to 1.69 mtoe in 2010/11. Interestingly, the total oil demand for transportation in the other three cities taken together is around the same level as that of Delhi alone. In 1990/91, the gasoline and diesel consumption in Calcutta, Mumbai and Bangalore was 0.27 mtoe, 0.35 mtoe and 0.18 mtoe respectively. By 2010/11, the estimated increase would be 1.3 times, 2.1 times and 3.7 times in Calcutta, Mumbai and Bangalore respectively.

Delhi recorded the highest per capita oil demand for personal mobility followed by Bangalore, Mumbai and least in Calcutta. Annual per capita oil demand is estimated to increase from about 64 kgoe in 1990/91 to 112 kgoe in 2010/11. In Mumbai, the increase would be from 33 to 51 kgoe, Bangalore from 41 to 86 kgoe during the same 20 year period. While in Calcutta, the annual per capita fuel requirement would remain around 21 kgoe. Also, without altered policies, there is observed to be a greater dependence on diesel compared to gasoline in the transport sector in coming years. Due to the high price differential between price of diesel (around Rs 11 per litre) and gasoline (Rs 24 per litre), people are increasingly showing preference for diesel based passenger cars/jeeps.

6.2.5.2. Emissions

Delhi recorded the highest level of pollution loading of CO, HC, NO_x, SO_2, TSP and Pb relative to the other cities.

CO emission factor of gasoline vehicles are higher compared to diesel. Annual emission of CO in Delhi was 177740 tonnes (t) in 1995/96, which was 28% higher than in 1990/91 and in the next fifteen years, it would increase by 16%. Annual CO emissions in the other three cities is almost three and a half times less than that of Delhi in 1995/96. With very poor combustion efficiencies in two-stroke scooters, motorcycles and autorickshaws, they nearly contributed in 1995/96 nearly 55%, 44%, 50% and 67% of total CO emissions in Delhi, Calcutta, Mumbai and Bangalore respectively. Contribution by two wheelers would further go up to 58%, 64%, 62% and 85% during 2010/11. With the country's liberalization policy, the penetration of new technology cars started in 1995, which is coupled with the introduction of catalytic convertor in cars from April 1, 1995 in Delhi, Calcutta and Mumbai. These have resulted in drop in share of CO emissions from cars between 1995/96 to 2010/11. Share of CO emissions is likely to decrease from 39% to 27% in Delhi, 53% to 33% in Calcutta, 32% to 17% in Mumbai and 22% to 8% in Bangalore during the fifteen year period. Except in Bangalore, all other cities are likely to have increasing share of CO contribution by bus.

Emission factor of HC from gasoline vehicles are higher compared to diesel. Annual emission of HC in Delhi was 71450t, which is 30% higher than the present level and is expected to increase further to 17% by 2010/11. Like CO emission, HC emission in the three other cities is also three and a half times less than that of Delhi in 1995/96. With almost 20-40% of the fuel supplied to two stroke engines are exhausted without being combusted, would lead to over 80% contribution of HC emission by scooters, motorcycles and autorickshaws in Delhi during 1995/96. The corresponding values for Calcutta, Mumbai and Bangalore are 71%, 76% and 86% respectively. By 2010/11, two stroke engine driven vehicles will contribute 84%, 85%, 85% and 95% HC emission in Delhi, Calcutta, Mumbai and Bangalore respectively.

Diesel driven vehicles emit more NO_x compared to gasoline. Emission rate of NO_x is estimated to be the highest (83000 t in 1995/96) in Calcutta and would continue to remain around the same level in the coming years. However in Delhi, annual NO_x emission is 43930t, which is 32% higher compared to the 1990/91 level and would increase by 70% by 2010/11. Similarly, in Mumbai the 1995/96 emission loading was 21550t, which is 18% more compared to 1990/91 and 69% by 2010/11. In Bangalore, the emission level is 13160t during 1995/96 which is 72% higher compared to the 1990/91 level but this would decline to 63% by 2010/11. Buses contribute nearly 65%, 33%, 83% and 79% of NO_x emission in Delhi, Calcutta, Mumbai and Bangalore respectively.

Contribution of SO_2 emission is higher in diesel vehicles compare to gasoline. Highest emission (5180t) of SO_2 is observed in Delhi during 1995/96, followed by Mumbai 3100t, Calcutta 1550t and Bangalore 1840t respectively. With respect to the 1990/91 loading, SO_2 emission in Delhi, Mumbai, Calcutta and Bangalore in 1995/96 was 35%, 28%, 8%, 72% more. These would increase further to 116%. 86%, 45% and 114% respectively by 2010/11 .

Diesel vehicles emit significant TSP compared to the gasoline ones. Delhi recorded the highest level of emission loading in 1995/96 (9440t). This is 34% higher compared to the 1990/91 level and it is further going to increase to 51% by 2010/11. Mumbai and Bangalore had the same TSP level of 3050t in 1995/96. The rate of increase of TSP emission in Bangalore would be very significant (around 135%) compared to Mumbai by 2010/11. Buses would contribute as high as 45% emission of TSP in Mumbai. While around one third of the TSP share would be contributed by buses in Delhi and Bangalore. In the case of Calcutta, only around 9% of the emission share is currently contributed by buses and is expected to decline marginally to 8% by 2010/11.

Pb is only emitted by gasoline vehicles. Delhi recorded the highest loading (102t) of Pb in 1995/96, which is 30% higher compared to 1990/91 but would decrease after 2000/01 steadily with the gradual lead phase out programme introduced in the country. Annual Pb emission in 1995/96 in Calcutta, Mumbai and Bangalore was 31t, 26t and 25t respectively and would decline steadily with lead phase out programme.

6.2.6. Abatement strategies and reduction potential

The study has illustrated the effect of two much discussed transport policy issues: - (i) reducing urban congestion by facilitating a shift towards use of flexible public transport (bus) defined as scenario 1 and (ii) gradual introduction of clean technologies and alternate fuel vehicles - for reducing the potential energy demand and emission defined as scenario 2. These two scenario results are analyzed with respect to the BAU scenario results to determine the physical benefits in terms oil savings and reduction in emissions.

Scenario 1 in 2010/11 assumes: (a) 80% of the total travel demand would be catered by bus in all the four cities compared to 66%, 26%, 59% and 80% in the BAU scenario, and (b) dependence on personalized vehicles would drop. While scenario 2 in the next decade (2001-2011) assumes: (a) a greater penetration of 4-stroke technologies in the four cities, (b) introduction of compressed natural gas based cars, taxis and buses; propane based autorickshaws; and battery operated autorickshaws, cars and buses, and (c) phasing out of leaded gasoline from the cities.

Potential for energy savings during 2010/11 is over 55% in Calcutta if the recommendations of scenario 1 and 2 are in place. While in Bangalore, Delhi and Mumbai the savings potential are 24%, 22% and 15% respectively. This means with more buses and introduction of clean fuel and technology, per capita energy savings during 2010/11 would be 25 kgoe in Delhi, 21 kgoe in Bangalore, 12 kgoe in Calcutta and 8 kgoe in Mumbai.

With more buses and cleaner fuel and technology in 2010/11, potential for CO reduction with respect to the BAU case is found out to be the maximum in Calcutta 74% and least in Mumbai 28%. Further, in Delhi and Calcutta, CO emission level in 2010/11 would be lower than the 1995/96 loading level, but in Mumbai and Bangalore, it would be marginally higher. Similarly, HC reduction potential is the highest in Calcutta 80% and the least in Mumbai 28% in 2010/11. HC emissions in Delhi and Calcutta during 2010/11 is lower than its 1995/96 level, while in Mumbai and Bangalore it is higher by 13% and 9% respectively. NO_x emissions with more buses and cleaner fuel and technology compared to the BAU scenario in 2010/11 would reduce by 15% in Delhi, 22% in Mumbai, 16% in Bangalore. While in Calcutta NO_x emissions level would increase by 12%. SO_2 emission reduction potential is 46% in Calcutta, 27% in Mumbai, 24% in Delhi but would increase by 5% in Bangalore. Reduction potential of TSP is highest in Calcutta 59%, Delhi 37%, Bangalore 34% and Mumbai 21% respectively. Reduction potential of Pb is considerable in 2010/11 compared to the BAU scenario in all the four cities with Delhi 60%, Calcutta 83%, Mumbai 31% and Bangalore 73% respectively.

The current air quality strategy in developed economies is based primarily on a search for technological fix, which is a transport supply side management option. However, in a rapidly growing developing economy like India, there are limitations to a strategy focused primarily on affecting automotive technology. With growing traffic congestion and inadequate investment in road development, transport demand side management options are critical and needs to be more vigorously used than at present, having usually failed due to: lack of public transport alternatives, lack of staff for design and enforcement; and political unwillingness to implement and enforce. It is desirable therefore, to integrate the supply side interventions with demand management measures, if the ultimate objective is to secure improved levels of air quality.

6.2.7. Financial viability of alternate fuels

On the basis of the ratio of net present value the cost of a CNG car compared to a petrol driven car the study reveals that a CNG car is a financially attractive even with a very high discount rate of 15% with assumed life of cars to be more than 15 years. Similarly, a battery operated vehicle as compared to a petrol driven autorickshaw becomes financially viable within 9 years but with a very low discount rate of 6%.

High upfront costs of these two alternate type of technologies compared to the conventional ones can be overcome by providing soft loan facilities to acquire the new range of technologies together with a set of fiscal disincentives for the use of conventional and inefficient technologies.

6.3. Power sector

6.3.1. Total and per capita electricity consumption

Delhi is seen to have a much higher level of electricity requirement as compared to the other cities. In 1988/89, Mumbai had the largest requirement (8651 GWh) followed by Delhi (7636 GWh) and Calcutta (5314 GWh). However, since 1991/92, Delhi has had the largest requirements and it is estimated that by 2001/02, its requirements would be nearly 2 times that of Mumbai and about 3 times that of Calcutta. Over the period 1988/89 to 1994/95, the requirement in Delhi has increased 3.5 times while the increase is about 1.7 and 1.6 times respectively for Calcutta and Mumbai.

A comparison of the intensity of power consumption (non-industrial) in the 3 cities revealed that Delhi has had the highest intensity followed by Mumbai and then Calcutta since 1988/89. Moreover, the annual rate of growth of per capita consumption is also highest in Delhi (6.8%) as compared to Calcutta (1%) and Mumbai (2.8%) over the period 1988/89 to 1994/95. In 1994/95, Delhi's per capita consumption is 2.2 times higher than Calcutta while it is 1.3 times that of Mumbai.

6.3.2. Need for reliable power supply from grid

The rapidly increasing electricity requirements trends in the cities indicate the need for directing concern towards enhancing the power supply situation to keep up with demands. With increased levels of power shortages in the country coupled with an unreliable power distribution network, the use of decentralized generating systems has seen a sudden spurt in activity over the last decade both in the residential as well as in the industrial & commercial sectors. At the city level, the diesel based gensets are a major source of air pollution and especially detrimental to human health since they are run in congested commercial areas and residential complexes and emit NO_x, SO_2 as well as TSP at the ground level apart from creating noise pollution. However, emissions from diesel generators could not be estimated due to lack of data on number of diesel generators in use and their utilization pattern. It is therefore necessary to minimise the use of gensets in the cities for which it is essential to ensure adequate power generation capacity as well as a reliable power distribution network.

Planning for adequate power supply should include the making of accurate projections of demands, timely planning for capacity additions and improving the efficiency of the supply system by reducing T&D losses for bridging the demand-supply gap in the country.

It is likely that the high consumption intensity in Delhi is partly due to the climatic conditions in the capital (hot and dry in summers and cold in winters) leading to the additional use of space conditioning devices in the city. But, the rapid increase in per capita consumption levels over the past decade in Delhi seems to suggest the play of other factors as well such as increasing levels of disposable incomes and a change towards energy intensive lifestyles among a significant fraction of the population. A rational electricity pricing structure should be set up in order to restrict high levels of consumption and to ensure adequate revenue generation for the utilities' maintenance.

6.3.3. *Need for privatisation and reforms*

This study has not quantified the level of shortages and unmet demands in the cities, however, discussions with power suppliers in the cities has indicated that the extent of forced outages and grid failures is more frequent in Delhi than in Calcutta and Mumbai. This seems to indicate that the private licensees are better managed and have been able to plan for capacity enhancements as well as technological upgradation both in the generation as well as transmission of power. Calcutta is mainly a case in point where the power supply situation was extremely uncertain till the late 1970s. But, since the CESC took over generation as well as distribution for the CMA, the situation has become quite reliable. In case of Mumbai as well, TEC has been able to consistently maintain a reliable power supply to its licensed area by planning for capacity enhancements, improving technologies used (and therefore efficiencies) and planning ahead for growth in demands.

Even though this study provides a small sample for making a case, it does suggest that private licensees have been able to ensure a more reliable supply of electricity. Against this background, it may be worthwhile to carry out an in-depth assessment of the functioning of the private licensees versus the State Electricity Boards. Another option would be to strengthen the capabilities of the Centralized grid so that surplus power may be transferred freely from one region to another.

6.3.4. Share of local generation

Analysis has revealed that the share of power requirement by the city which is met through purchases from the neighboring regions, has been increasing rapidly in Delhi - from a level of 29% in 1988/89 to about 55% in 1994/95. However, in case of Calcutta and Mumbai, the CESC and TEC have enhanced their own generating capacity over this period and their respective shares of purchases have decreased from 55% to 42% in Calcutta and from 43% to 32% in Mumbai over the same period.

6.3.5. Energy use and specific fuel consumption norms

In 1994/95, Delhi consumed 5.3 million tonnes of coal, 42 million litres of oil and 217 million cubic metres of gas while Calcutta used 3.9 million tonnes of coal and 28 million litres of oil for generation of power within the two cities.

In terms of efficiency of operation itself, most of the units in Calcutta are more efficient than those in Delhi. This is reflected by the specific fuel consumption levels. The average specific coal consumption in Delhi is about 0.82 Kg/kWh as compared to 0.6 Kg/kWh in Calcutta (the old units of Mulajore & New Cossipore have 0.94 Kg/kWh). Specific oil consumption figures also indicate that units in Delhi have much higher levels of oil consumption per unit of power generated when compared to those in Calcutta. It must be noted however, power plants in each of the cities are meeting the emission standards set by CPCB for TSP.

6.3.6. Emissions

The location of plants in and around the cities does not have a bearing on the availability of power in a city since capacity enhancements are planned for at the regional or national level rather than at the city level. Power may be drawn to various locations from the grid and supply to a city may be based even in other states of the country. The only consideration with respect to siting of power plants is therefore with regard to the impact of emissions from power plants on the air quality and therefore on the health of the population exposed to these pollutants.

The level of air pollutants released into the city's environment depends not only on the total quantum of power generated in the city but also on the fuel used (coal, oil or gas), the quality of the fuel (ash and sulphur content of the fuel), the combustion technology used as well as the efficiency of the control equipment used.

A comparison of the estimated resultant emissions in each of the 3 cities for 1994 indicates that TSP is the main pollutant in both Delhi and Calcutta - estimated at around

86,000 tonnes and 81,000 tonnes respectively. Both these cities largely have coal based power stations where TSP is the major pollutant. Mumbai has a significant level of gas based capacity and TSP emissions were of the order of about 4,000 tonnes only. The levels of TSP compared per unit of power generated locally indicate that Delhi, Calcutta and Mumbai emitted 12.2, 13.4 and 0.57 tonnes/GWh of TSP in 1994/95. This index has improved marginally in 1994/95 from 1988/89 (by about 1%) for Delhi and Mumbai due to improved specific fuel consumption. In case of Calcutta, the improvement is about 5% since some generation has shifted from the use of the stoker fired technology to pulverized fuel technology and the use of multi cyclones in the old units has been replaced with ESPs which are more efficient. Calcutta has the highest index for TSP emissions which may be attributed to the use of only coal based generation in this city.

Even though the emissions of NO_x and SO_2 are considerably lower than that of TSP at present, it is observed that their levels are increasing rapidly in each of the 3 cities. Taking the toxicity levels of pollutants into account, it is expected that the emissions of NO_x and SO_2 would soon be cause for concern in these cities. This concern basically stems from our finding that the projected levels (in tonnes) of these 2 pollutants is of a similar magnitude in 2001/02 as that of TSP in the cities in 1988/89 (since there are no controls on their emissions). It is therefore advisable to focus attention towards these pollutants at an early stage and consider the use of technological options for their control.

6.3.7. *Abatement strategies and reduction potential*

An analysis of alternative scenarios indicates that it would be possible to significantly reduce the emissions of these pollutants using retrofit technologies such as sorbent injection for SO_2 control, low NO_x technologies and combined SO_2-NO_x reduction technologies. With the adoption of low-NO_x technologies in the existing power plants, NO_x emissions in 2001/02 can be maintained at 1988/89 levels in both Delhi and Calcutta, as compared to the base case where emissions increased by 1.7 times in Delhi and 1.9 times in Calcutta over this period. The adoption of sorbent injection technology in the existing power plants after 1997/98, is estimated to stabilize SO_2 emissions in 2001/02 at 1988/89 levels in both Delhi and Calcutta, as compared to the base case where these emissions increase by 1.7 times in Delhi and 1.8 times in Calcutta over this period. With combined SO_2-NO_x reduction technologies, emissions of NO_x in 2001/02 reduce from 54000 tonnes (base case) to 8000 tonnes in Delhi and by from 41,000 tonnes to 6,000 tonnes in Calcutta, while the emissions of SO_2 in 2001/02 reduce from 69,000 tonnes (base case) to 10,000 tonnes in Delhi and from 64,000 tonnes to 11,000 tonnes in Calcutta.

At this juncture, the adoption of control technologies for NO_x & SO_2 are hindered by the absence of standards and the costs which would be involved. It is therefore suggested that some emission standards for containing the emissions should be set up to motivate investments towards the adoption of these cleaner technologies.

The index of NO_x emissions is highest in Delhi (5.8 tonnes/GWh) followed closely by Calcutta (5 tonnes/GWh) and then Mumbai (1.28 tonnes/GWh) in 1994/95. Since, there is no technology in place for control of NO_x emissions as yet, the difference in emissions between Delhi and Calcutta is expected to be mainly due to the difference in operating efficiency of the units as discussed above. The index of SO_2 emissions is almost comparable in case of Delhi and Calcutta (approximately 7.5 tonnes/GWh), while it is about much less in case of Mumbai (1.1 tonnes/GWh).

Attempts to harness renewable sources (wind, small hydro and solar energy) as well as advanced clean fuel (gas based) technologies should be made as far as possible. However, given that coal would continue to be the dominant fuel for power generation in the coming decades, it is also essential to consider technological options for ameliorating air pollution due to the existing power plants.

Analysis of the alternative scenarios indicates that there is significant potential to reduce emission levels (especially of TSP) with the use of very simple and inexpensive options such as better housekeeping and efficiency improvement of control devices. Better housekeeping is expected to reduce emissions by about 10% at no additional cost. Similarly, with better maintenance of the pollution control devices, efficiencies of 99% in ESPs and 90% in case of multi cyclones can be achieved. With such efficiencies, the TSP levels are estimated to drop from 112 to 23 thousand tonnes in Delhi and from 74 to 31 thousand tonnes in Calcutta in 2001/02. Both these options are "win-win situations" and should definitely be implemented in all power plants as a first step towards improving the environmental quality.

The estimated benefits from washing of coal estimated for the city of Delhi indicate that by 2001/02, TSP emissions could reduce to 69,000 tonnes from 112,000 tonnes in the base case. Since, a policy directive for coal washing has already been passed, such reductions are likely to be achieved across other plants as well where the ash content of coal being used was more than 35%.

Clean technologies for the future such as atmospheric fluidized bed combustion, pressurized fluidized bed combustion and integrated gasification combined cycle should be promoted since they would significantly reduce emissions as well as lead to better efficiency in generation. In the short term, it may be beneficial to invest in R&D and to later adopt these technologies. Costs for coal washing and for adopting the advanced technologies may not be representative in the true sense, since the environmental benefits are not considered. Internalizing these externalities may well present a different scenario and it may be worthwhile to consider an economic cost-benefit analysis to arrive at viable options for the future.

6.4. Industrial sector

A detailed analysis of the energy intensive industries in Delhi for the years 1989/90 and 1993/94 has been carried out using the ASI data. The study is restricted to only Delhi due to the non availability of disaggregate data on energy use pattern and the related parameters in this sector for the rest of the cities. Only the following energy intensive industries have been analyzed as they together consume the majority of energy consumption share in all manufacturing industries together in the city.

6.4.1. Food products, sugar and breweries

The food products, sugar and breweries industry (NIC code 20-21) in Delhi has undergone certain structural changes in the forms of (a) technological interventions, (b) shift towards higher value added products, and (c) improvements in energy efficiency. Though, the pollution emissions from this sector have increased marginally, there has been a significant reduction in the TSP emissions while emissions of the remaining pollutants (SO_2, NO_x, CO and HC) have increased considerably.

6.4.2. Basic Chemical and chemical products

The basic chemicals and chemical products industry (NIC code 30) in Delhi seem to have only experienced certain attempts to energy conservation/efficiency improvements while the production levels have shown decline effecting the sectoral performance. Though, the pollution emissions from this sector have increased marginally, there has been a significant reduction in the TSP emissions while emissions of the remaining pollutants have increased considerably.

6.4.3. Cotton textile

The cotton textile industry (NIC code 23) in Delhi has seen a declining trend with decline in production levels and industrial operations. While the pollution emissions from this sector have increased, there has been a marginal reduction in the TSP emissions whereas emissions of the remaining pollutants have increased significantly.

6.4.4. Basic metal and alloy

The basic metal and alloy industries sector (NIC code 33) in Delhi has undergone some structural changes coupled with energy efficiency improvements. The pollution emissions from this sector have reduced considerably, with a significant reduction in the TSP emissions while emissions of the remaining pollutants have marginally increased.

6.4.5. Rubber, plastic, petroleum and coal products

The rubber, plastic, petroleum and coal products industry (NIC code 31) has undergone some structural changes in the form of technological improvements and energy efficiency. The pollution emissions from this sector have increased, with a marginal increase in the TSP emissions and significant increase in emissions of the remaining pollutants.

6.4.6. Non-metallic mineral products

The non-metallic mineral products industry (NIC code 32) has not shown a considerable change except for a few technological changes, but with no encouraging effects on the energy consumption/efficiency levels The pollution emissions from this sector have increased considerably, with a considerable increase in the TSP emissions and significant increase in emissions of the remaining pollutants.

6.4.7. Wool, silk and man-made fibre textile

The wool, silk and man-made fibre textile industry (NIC code 24) has shown a decline in its performance though there have been some technological interventions. The pollution emissions from this sector have increased marginally, with a marginal increase in the emissions of all pollutants.

6.4.8. Paper, paper products, printing and publishing

The paper and paper products and printing, publishing and allied industry (NIC code 28) has, though undergone certain structural changes in the form of technological interventions, there have been no significant direct effects reflected in the desired forms. The pollution emissions from this sector have increased considerably, with a considerable increase in the emissions of all pollutants.

6.4.9. Location policy

Developing industrial estates, parallel to the industrial growth, and ensuring proper location and pollution control status of industries is an essential task that needs to be taken up on a war footing in all the cities. This needs an on-line planning for the industrial development by a combination of concerned agencies such as industrial development corporations, city development authorities and pollution control boards. Especially, the cities with potential growth, such as the "growth centres" identified by the Town & Country Planning Organization, could be a focus for concentrating industrial estate development efforts in future. Another major factor that could be of prime consideration for a planned industrial development in cities is "assured power supply and availability of infrastructure" which has been well pointed out in the report of the National Commission on Urbanization (Chapter 15 on Energy) as Delhi is attracting industry because of the more assured supply there as compared to the adjoining smaller towns. The industrial growth in Bangalore was also accelerated primarily because the Karnataka government promised assured power supply as one of the incentives to attract industry to that area. On the other hand, the severe power crisis in Calcutta has effectively put a break to the industrialization process in that region. Therefore, a good tool to aid industrial development in an environment friendly manner is to give incentives to industries such as assured power supply and infrastructure at low rates so that stress on large cities could be reduced and diverted to cities with potential growth. Differential tariff such as low tariff rates for new industries which are to be located in these potential growth centres is another tool to attract industries and thus reduce stress on large cities.

6.4.10. Need for a detailed inventory

Lack of a detailed inventory of industries in cities with essential details such as capacity, energy consumption and environmental performance is a major obstacle for carrying any study on industrial pollution in cities. Maintaining proper industrial database, with complete inventory of information and emissions status is very much essential. There should be a central place such as the concerned Pollution Control Board where this could be maintained and be available for on-line usage by various planning and development agencies and research groups.

Periodical (say once in a week or fortnight) publication of environmental performance (in terms of emissions) of the industries (in cities) in popular media such as news papers is a good instrument to keep the industry alert for keeping its environmental performance upholding.

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